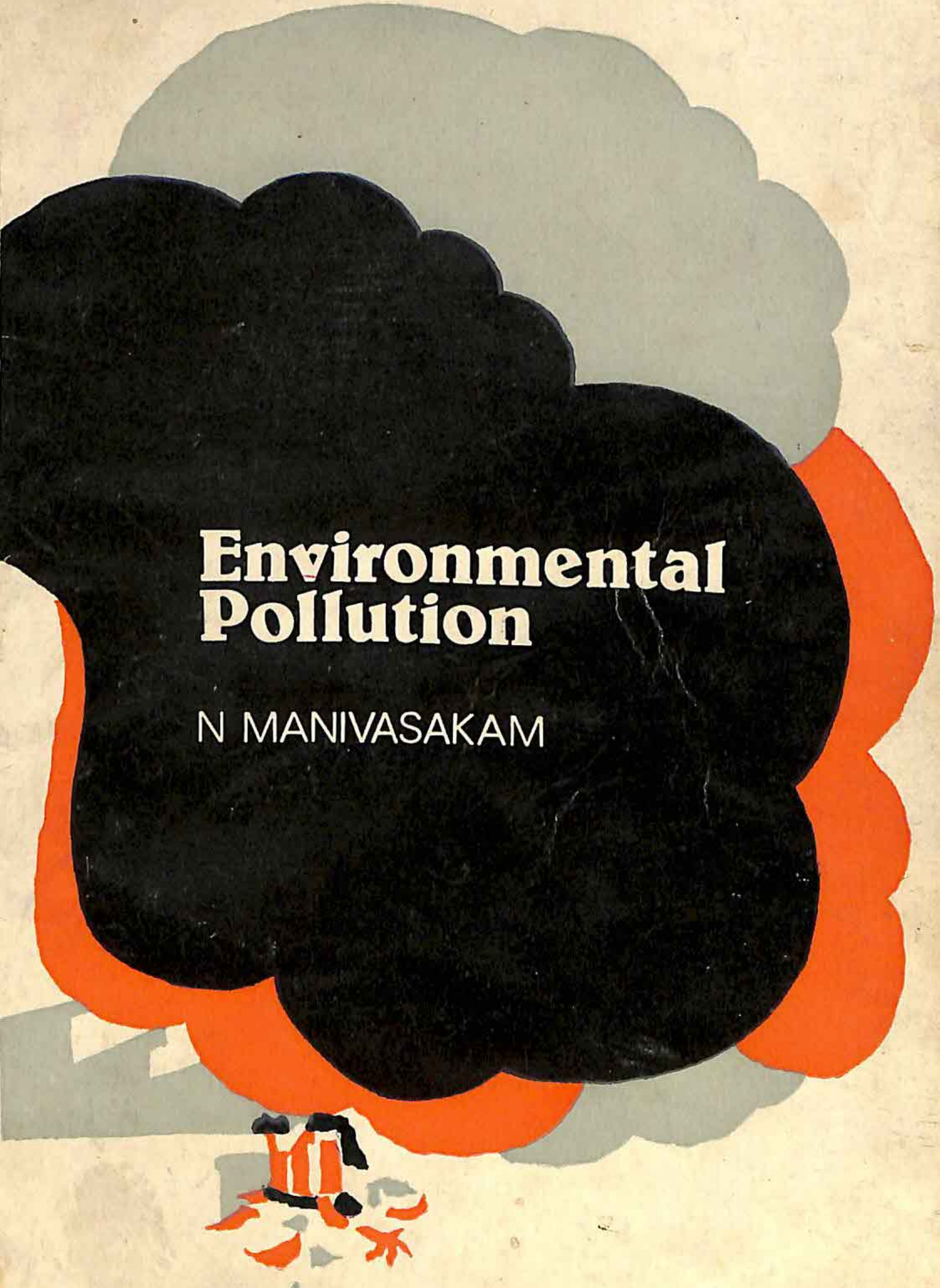

Environmental Pollution

N MANIVASAKAM

ENVIRONMENTAL POLLUTION

POPULAR SCIENCE

ENVIRONMENTAL POLLUTION

N. Manivasakam

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First Edition 1984 (*Saka* 1905)
Second Edition (*Reprint*) 1989 (*Saka* 1911)

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Rs. 16.00

Published by the Director, National Book Trust, India
A 5 Green Park, New Delhi 110016

DEDICATED TO
My Parents
C.K. NATARAJ & ARUNAGIRI AMMAL
Wife
SIVABAKIAM
and Son
SAKTHI KUMAR

Preface

There is considerable literature dealing with environmental pollution, but most of the information is scattered through many scientific and technical journals and comparatively few books on the subject have been written. This book has been written to fill the need for a one-volume scientific discussion on the major types of environmental pollution—air, water, soil, thermal, radiation and noise pollution—and their impact on man and on the environment.

This book is divided into eight chapters each of which covers a particular aspect of environmental pollution. Every chapter is discussed point by point and unnecessary descriptions are omitted. It is to be mentioned, that though the author's training has been in the physical sciences, emphasis has also been made on biological and ecological principles.

This book could serve as a useful text for students of environmental concerns and will be particularly useful for students undergoing Public Health Engineering Course. It is also hoped that the book will prove useful to teachers as an aid in incorporating discussions on environmental problems in existing courses ; and to others as a scientific introduction to pollution and its control.

I am deeply indebted to Thiru G. Sudhakar, M.Sc., M.Ed., Assistant Professor, P.S.G. College of Arts and Science, Coimbatore for his valuable help extended throughout the preparation of this manual. A special debt of gratitude is due to Mr. S. Murugesan who assisted in preparing the chapter "Air Pollution". There have also been a number of people whose assistance in the preparation of this material, I gratefully acknowledge. Most especially, I would like to thank Mr. N. Jayaprakash, Indian Institute of Technology, Madras, Mr. N. Raveendran, M.Sc. (Agri.), Tamil Nadu Agricultural University, Mr. A. Sundaramurthy, University of Madras and to Shri M.P. Subramaniam for their valuable suggestions and criticisms.

I am also grateful to World Health Organisation and Indian Council of Medical Research for their kind permission to reproduce some of the portions from their publications.

Lastly, it is a pleasure to me to express my sincere thanks to National Book Trust, India, for their keen interest shown towards the publication of this book.

N. MANIVASAKAM

Acknowledgement

My grateful thanks to Dr. V. KAPALI, Director of Public Health & Preventive Medicine, Government of Tamil Nadu, Madras, for his kind permission to publish this book and to Shri G. Swaminathan, Chief Water Analyst, Coimbatore who has created in me an enthusiasm to write books of this type.

N. MANIVASAKAM

The author is grateful to Dr. O. C. Taylor & Dr. E.F. Darley (Retd.), Statewide Air Pollution Research Centre, University of California for having offered the colour transparencies

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"The threats of pollution are real. Their economic consequences are real. Their health consequences are real. There are sufficient data to make strong cases based on facts."

—**Malvin J. Josephs,**
Environ. Sci. Tech. 1 : 525 (1967).

I

Environmental Pollution—An Introduction

THERE IS NO need to explain the term environment. It comprises, air, water and land. It is not easy to give a precise definition of "pollution" or of the word "polluting". The Oxford English Dictionary defines 'pollute' and 'pollution' as follows :

Pollute : destroy the purity or sanctity; make (water etc.) foul or filthy.

Pollution : the act of polluting.

It is easier to describe pollution than to define it. Environmental pollution may be described as the unfavourable alteration of our surroundings and occurs mainly because of the action of man. Environmental pollution takes place through changes in energy patterns, radiation levels, chemical and physical constitutions and abundances of organisms. Pollution, sometimes causes visible harm; sometimes it befouls the air and poisons fish and other aquatic animals in rivers and lakes. Pollution includes release of materials into atmosphere which make the air unsuitable for breathing, harm the quality of water or soil; and give out substances which damage the health of human beings, plants and animals. Though the other environmental pollutants, odour and noise only irritate or disturb they can also sometimes, be a danger to health. The effects of pollution to our biosphere are numerous and are increasing tremendously. Unless otherwise checked, they could make the whole planet uninhabitable.

Air pollution in cities has mounted as more and more people have crowded in. Water pollution has increased with the growth of industry as well as of population. The disposal of solid waste from industrial, commercial and household sources has become a major concern. In addition to these, noise has become more acute due to a tremendous increase in numbers of motor vehicles, industrial operations and building constructions. Radioactive materials and certain other pollutants have begun to spread widely through the atmospheric and ocean systems of the world to cause mutations* and other birth defects.

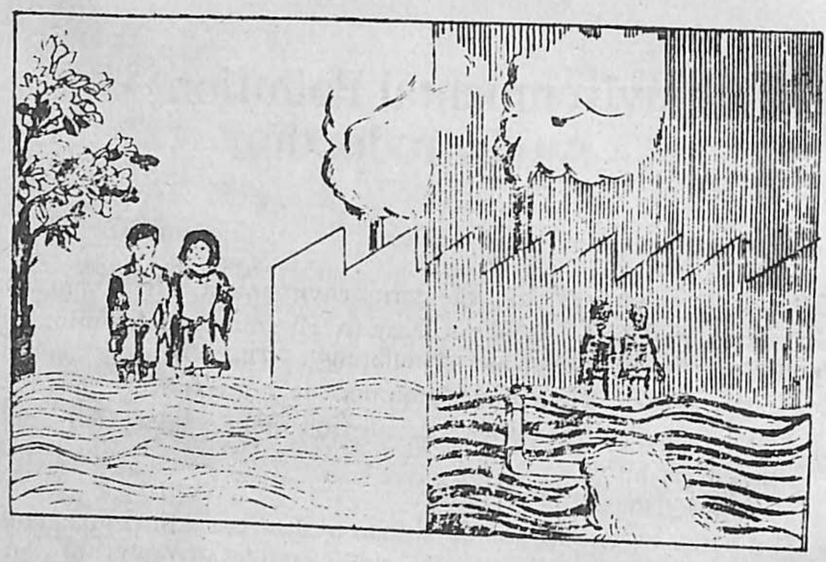

Fig. 1 Pollution damages the health of human beings, plants and animals

Environmental Problems of Air, Water and Land

Rapid industrialisation results in the deterioration of air quality. This is happening in almost all urban areas throughout the world. Utilization of coal as fuel and the incomplete combustion of it give out soot, sulfur and other compounds into the atmosphere. The rapid increase in the number of motor-cars, trucks and other engines that use petroleum fuels has added a new dimension to the

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* *Mutation* : Genetic change when transmitted to offspring gives rise to heritable variations.

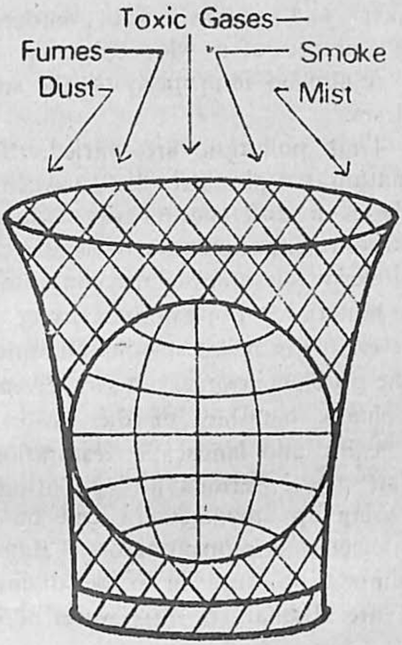

Fig. 2 Our breathing air becomes a waste basket

urban air pollution problem. Combined with the traffic congestion during peak hours, the hydrocarbon and other toxic chemicals emitted by motor vehicles have resulted in air pollution levels that endanger health. The conditions of the atmosphere have further been exacerbated by the operation of coal and oil burning electric power plants within metropolitan areas. The net effect of these and other forms of air pollution can be cumulative over extended periods in certain topographical and meteorological situations. In short, the industrial revolution and our modern civilization turns the air we breathe into a waste basket in which dust, noxious fumes, toxic gases, mist, odour and smoke are thrown.

Water pollution is a serious problem ever since sewage and industrial effluents are being disposed out into the rivers. Population growth adds both to pure water, requirements and to the generation of sewage and waste products. Industries need a wider variety of chemicals and/or metals which are later discharged into rivers, streams, lakes and oceans. The modern techniques of agriculture involve the use of a wide spectrum of fertilisers and pesticides which when applied improperly to the soil will find their way into water courses.

The effects of land pollution are varied. They range from chemical contamination to physical disfigurement and aesthetic degradation. There is a difference between land pollution and other types of pollution, i.e. pollutants come more or less to rest on land. However, modern techniques of recycling, make these waste material into usable materials. For example, paper products, metals, glass and plastic meterials can be recycled. Dumping of raw wastes on ground makes the problem worse. It has given way to a rather elaborate and systematic handling of the wastes with increasing attention to public health and landscape restoration. Solid wastes when burned in air create serious air pollution problems. The burned products going up smoke-stacks can be reconverted into solids by means of electrostatic precipitators. But these solids once again have to be dumped on land or to be discharged into water. When solid wastes are discharged into water bodies, pollution of water occurs.—

Modern agricultural practices and newer technological processes have introduced another kind of pollution. Inorganic fertilizers—nitrogen. phosphates and potash—have been applied in larger quantities to farm lands. These phosphates and nitrates when carelessly applied to crops or through run-off may concentrate in lakes and estuaries, causing algal blooms by which whole stretches of water become choked, plants rot, all oxygen is used up, and fish die. In addition to fertilizers, numerous pesticides, insecticides and herbicides are also applied. These substances are reported to contaminate both surface waters and ground waters. Some of them are carried to distant places by winds, rains and rivers. These are reported to be found even in high mountains and in seaside swamps in many countries and they may be injurious to human health or to animals, birds and fish when present in larger quantities.

Yet another kind of pollution has more recently come to prominence as a result of the invention of nuclear power and nuclear weapons. Radioactive materials find their way into the atmosphere and water courses and these are reported to cause mutagenetic effects.

Even the limited number of nuclear power plants in operation will create environmental and health problems of the utmost severity within two or three decades. Use of reactors has increased the problem and no means have yet been found to eliminate the danger caused by the radioactive particles.

Lastly, attention should be given to pollution caused by noise. Increased industrial operations, motor, and air traffic and our modern day-to-day life activities contribute much to noise pollution.

The first and most important source of pollution is the growing population. The earth is now crowded with people, and all of them consume resources and create wastes. Population growth clearly has a great deal to do with increase in pollution and it causes disproportionately a negative impact on the environment. Pollution problems increase more or less in step with population growth. For example, as the population increases the dischargeable human wastes are also increased. If the per capita amounts of pollutants and wastes were to remain constant, the residue loading of the environment would rise precisely in relation to the growth of population. This is acceptable, within limits, given the capacity of air, water and land to absorb, dilute, carry away and otherwise render pollutants harmless. But, it must be mentioned that in many places these limits have either been approached or have been exceeded.

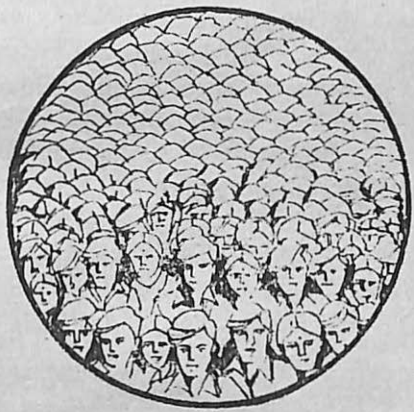

Fig. 3 Growing population—The major cause for increased pollution.

Another important factor to be remembered is the impact of rapidly changing industrial methods on the environment. We should not forget that the natural processes which keep the planet habitable in the short-term are primarily cyclic. Materials moving through these cycles, utilize solar energy and return to their original state before other process starts. In contrast, modern technology makes the materials to be removed from the limited geological deposits or from living systems and eventually they are discharged as wastes. Not only these wastes act as pollutants of natural cycle but also alter the composition of the atmosphere and disturb the balance of solar radiation. Thus man's industrial activities add more stresses on the biosphere and the ability of the biosphere to withstand these stresses is also decreased by such conversion of complex natural ecosystems to the simple ones.

To summarise, population density, and per capita gross national product (GNP) which is generally a result of industrialization are considered to be the general indicators of pollution sources. When a country or region moves towards higher levels in these two respects, it is likely to undergo environmental deterioration. To conclude, civilization itself cannot survive if the natural environment collapses and man must husband the resources of his planet if he has to survive.

II

Air Pollution

AIR POLLUTION CAN never be given a clear cut definition. Air is a mixture of many gases and moisture with some inert materials. Thus we cannot find 'clean air' in any part of the world. When we breathe, not only oxygen but also other gases and materials enter our respiratory system. Hence it would be appropriate to define air pollutants rather than to define air pollution. Air pollutants are the materials that exist in such concentrations so as to cause unwanted effects. On this ground, air pollution may be described as the imbalance in quality of air so as to cause ill effects. As in natural surface waters, different types of pollutants are continuously introduced into the atmosphere and are continually removed by the self purification processes of air. But, when the rate of pollution exceeds or when the self purifying capacity decreases, accumulation of pollutants occurs causing serious public health problems. Though there are natural pollutants such as smoke from forest fires, the discussion made in this chapter centres only on the pollution by man-made pollutants.

Pollutants can be conveniently classified into two main groups :

1) Gaseous pollutants, and
2) Particulate pollutants.

Gaseous Pollutants

These types of pollutants include substances that are gaseous in nature at normal temperature and pressure. Vapours of the compounds whose boiling point is below 200°C are also included in this category. The most important gaseous pollutants are carbon monoxide, oxides of sulfur, hydrogen sulfide, hydrocarbons, oxides of nitrogen, ozone and other oxidants.

Carbon monoxide : Carbon monoxide is released into the atmosphere mainly from the automobile exhaust. Next to carbon-dioxide, carbon monoxide is considered to be the most abundant pollutant and it may show wide diurnal variations in the urban atmosphere. Concentrations of carbon monoxide vary, depending upon the density of motor traffic. However, carbon monoxide is usually present in amounts far below the threshold concentration in areas where traffic is less.

Sulfur dioxide : Sulfur dioxide is one of the principal contaminants of air. Sulfur dioxide has its origin in the combustion of sulfur bearing fossil fuels. It is also present in appreciable quantities in air where coal is used as a fuel, e.g., electric power plants. Sulfur dioxide is also released from smelters where sulfur bearing ore is roasted, e.g., copper, lead and zinc smelting industries. Oil refineries, sulfuric acid manufacturing industries, fertilizer industries, and paper and pulp industries give out significant amounts of sulfur dioxide. Smelting operations are reported to cause heavy damage to agricultural and forest areas. Since sulfur dioxide is readily absorbed by water surfaces, soil and vegetation, deterioration and corrosion affects materials such as metals, paper, paints, leather, textiles, cement and other building materials.

Hydrogen sulfide and organic sulfide : Generally, sulfides cause odour nuisances when present even in very low concentrations. However, they are not released in appreciable quantities by industrial operations since the effluents are treated before they are exposed to the atmosphere. Natural gas refining, manufacture of coke, manufacture of paper, distillation of tar and petroleum, manufacture of viscose rayon and some other chemical processes produce hydrogen sulfide and mercaptans. The effluents from the above processes are burnt or absorbed in "purifiers," and hence serious problems do not occur. However, it is reported that hydrogen sulfide has killed many municipal workers who have entered large sewers to work.

Hydrogen fluoride : Hydrogen fluoride and other volatile fluorides are considered to be serious pollutants even when present in concentrations of 0.001 ppm by volume. Fluorides are liberated mainly from aluminium smelting industries. Manufacture of phosfate fertilizers, manufacture of ceramics and some of the foundry operations are also contributing fluorides. Hydrogen fluoride and silicon tetrafluoride are reported to be toxic to some plants in concentrations lower than 0.1 parts per billion. Hydrogen fluoride accumulates in leaves of plants and thereby causes animal fluorosis. Leaves and flowers of many plants are extremely susceptible to fluorides. Hence it is a major problem for agricultural units located in the vicinity of aluminium processing industries. Moreover, fluorides have the capacity to etch glass and can therefore cause considerable material destruction.

Hydrogen chloride : The concentrations of hydrogen chloride in the atmosphere are found to be less. However, higher concentrations can cause damage to vegetation and also to properties.

Oxides of nitrogen : The primary source of oxides of nitrogen is automobile exhaust. These are also produced as by-products of some chemical industries such as manufacture of nitric acid, manufacture of sulfuric acid by chamber process, and manufacture of nylon intermediates. It is reported that the products of combustion of natural gas contain upto 50 ppm of nitrogen. A report by E.L. Hall* indicates that internal combustion engines and industrial furnaces may release upto 500 ppm of oxides of nitrogen.

The oxides of nitrogen are the second most abundant atmospheric pollutants. These are extremely dangerous to human health. The effects are sometimes more severe than carbon monoxide.

Aldehydes and organic acids : These are present in lower concentrations in the atmosphere. The incomplete combustion of petroleum fuels and incomplete oxidation of lubricating oils form aldehydes and organic acids. Combustion of natural gas may also contribute to the formation of these materials.

Secondary Pollutants : All the gaseous pollutants that we have discussed so far belong to the category of primary pollutants. These pollutants are emitted and as such are not found in the atmosphere. In contrast to these primary pollutants, there are also secondary pollutants which are formed in the atmosphere. Evidences and experiments indicate that exhaust gases of automobiles have particular importance in the formation of secondary pollutants. For example, nitrogen oxides produced in the combustion of petroleum and other fuels emitted to the atmosphere, yield ozone in the presence of sunlight. It is to be noted that ozone is not emitted as such to the atmosphere but formed only from primary pollutants by the interaction in the atmosphere and thus constitutes a secondary pollutant. The ozone produced reacts with hydrocarbons to form a series of compounds such as aldehydes, ketones, organic acids, acylnitrates[*] and peroxy compounds. This type of photochemical reactions usually occur in smog. The term "smog" denotes a mixture of smoke and fog. It is reported that during a smog, the concentrations of ozone and oxidant materials are found to be high. According to the Haagen-Smit theory, ultraviolet rays in the sunlight break the nitrogen dioxide molecule to form nitric oxide and atomic oxygen. These products react with molecular oxygen to form ozone. The reactions may be represented as follows :

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* Stanford Research Institute, Los Angeles, F.L. Hall ; "Products of combustion of gaseous fuels" in proceedings of the 2nd National Air Pollution Symposium 1953.

1. $NO_2 \xrightarrow{hr} NO + O$
   Nitrogen dioxide $\xrightarrow{\text{U.V. rays}}$ Nitric oxide + Atomic oxygen
2. $O_2 + O \longrightarrow O_3$
   Molecular oxygen + Atomic oxygen ⟶ Ozone
3. $NO + O_2 \longrightarrow NO_3$
   Nitric oxide + Molecular oxygen ⟶ Nitrogen trioxide.
4. $NO_3 + O_2 \longrightarrow NO_2 + O_3$
   Nitrogen trioxide + Molecular oxygen ⟶ Nitrogen dioxide + Ozone.
5. $2NO_2 + O_3 \dashrightarrow N_2O_5 + O_2$
   Nitrogen dioxide + Ozone ⟶ Nitrogen pentoxide + Molecular oxygen.
6. $NO + O_3 \longrightarrow NO_2 + O_2$
   Nitric oxide + Ozone ⟶ Nitrogen dioxide + Molecular oxygen.

The liberated molecular oxygen reacts with molecules of aldehydes and oxygenated organic compounds which are activated by the absorption of light.

$$RCHO + O_2 \longrightarrow RCOOOH$$
$$RCOOOH + O_2 \longrightarrow RCOOH + O_3$$

---

[*] Acylnitrates — a group of organic compounds.

Thus once again ozone is liberated as a by-product.

On absorption of light energy, some of the aldehydes and ketones become free radicals. They react with molecular oxygen as follows :

$$HCO^{\cdot} + O_2 \longrightarrow HCO_3^{\cdot}$$

Free radical Free radical

The free radical $HCO_3^{\cdot}$ reacts further with molecular oxygen, nitric oxide, and hydrocarbons as follows :

$$HCO_3^{\cdot} + O_2 \longrightarrow HCO_2^{\cdot} + O_3$$
$$HCO_3^{\cdot} + NO \longrightarrow HCO_2^{\cdot} + NO_2$$
$$HCO_3^{\cdot} + \text{hydrocarbons} \longrightarrow \text{aldehydes, ketones, etc.}$$

Thus a cycle of reaction is set in motion and numerous products are formed. It is to be noted that ozone and nitrogen dioxide are evolved continuously throughout the cycle of reactions. Free radicals lead to several other types of free radical reactions and polymerisation and oxidation chain reactions.

Though these reactions are studied well, the chemistry of photochemical smog is still not clearly understood. Many attempts have been trialed to reduce the level of ozone in the atmosphere. Actually, if the amount of hydrocarbons released in the atmosphere is reduced, then the ozone formed will be utilized in the oxidation of nitric oxide to nitrogen dioxide. But unfortunately the levels of ozone have never decreased and the puzzle has not yet been solved.

Particulate Pollutants

Air-borne particulate materials consist of both solid and liquid particles. They vary in size and the size ranges from 0.01 micron* to 20 microns. Particles having a diameter of 20 microns are relatively large. Particles with least diameter are present in aerosols.** The particulate pollutants may be classified according to their nature and sizes, as follows :

Dust : Dust is formed by soild particles and their size range from 1 micron to 100 microns. However, dust particles with a size of 0.1 micron are also present in the atmosphere. Dust particles are : (i) entrained by process gases directly from the materials being handled or processed, e.g., coal; (ii) the off-spring obtained directly from the parent material when it undergoes a mechanical operation, e.g., sawdust from wood works and (iii) entrained materials used in mechanical operations, e. g., sand from sand blasting.

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* Micron=10^{-6} meter

** Aerosol—aerosol is a suspension of particulates in a gas.

Fume : The size of these particles are less than 1 micron. Fumes are generally formed from particles of the metals and metallic oxides. Fumes are formed by the condensation of vapours by sublimation, distillation, calcination, and by other chemical processes and chemical reactions.

Mist : Condensation of a vapour forms a liquid particle known as mist which is less than 10 microns in size.

For example : SO_3 (gas) $\overset{22^{\circ}c}{\text{———}}$ SO_3 (liquid)

Spray : Liquid particle obtained from the parent liquid by the mechanical disintegration processes such as atomisation is known as spray.

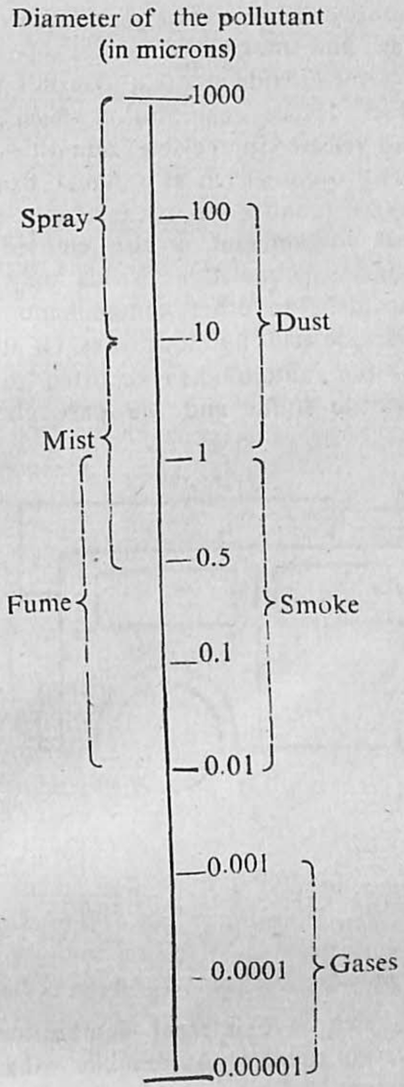
Smoke : This includes solid and liquid particles of size ranging from 0.05 to 1.0 micron and are obtained by the incomplete combustion of carbonacesous materials and formed by destructive distillation. Though, gaseous pollutants such as hydrocarbons, oxides of sulfur and oxides of nitrogen are produced by the incomplete combustion, only the solid and liquid paricles are termed as smoke.

The chart given on page 13 shows the approximate size ranges of both gaseous and particulate pollutants.

The composition of the pollutants has been studied extensively. It is reported that particulate contaminants contain about 22 metallic elements. The most abundant elements are silicon, calcium, sodium, aluminium and iron. Considerable amounts of lead, zinc, copper, magnesium and manganese are also present. Depending upon the nature of the industries the concentration of these metallic elements will vary. The proportion of lead increases as the vehicular traffic increases since lead tetraethyl is added as an antiknock to the petroleum fuel. Spectrographic analysis of the organic fraction reveals that a number of both aliphatic and aromatic hydrocarbons, organic acids, bases, phenols and varied types of complex compounds including some carcinogens are present in the atmosphere as particulate pollutants.

Source of pollutants

Though the sources of contaminants have been discussed above



with pollutants, a separate section is included as it will be helpful in understanding preventive measures for controlling air pollution. Man-made sources of pollutants can be classified as (i) stationary combustion, (ii) transportation, (iii) industrial process and (iv) solid waste disposal sources.

Stationary combustion processes yield mainly particulate pollutants such as fly ash and smoke, and oxides of sulfur and nitrogen. The amount of sulfur dioxide emitted, depends upon the content of sulfur in the fuel. Hence coal and oil which contain considerable amounts of sulfur release appreciable quantities of sulfur dioxide. High temperature processes such as thermal fixation of atmospheric nitrogen yield larger quantities of oxides of nitrogen. Carbon monoxide, a significant contaminant is also emitted from combustion. However, complete combustion yields only carbondioxide and not carbon monoxide. The other contaminants that are produced by combustion include acids and aldehydes. Of all the fuels used in stationary combustion, natural gas is reported to be the best as it contains only a little sulfur and the particulate emission is much less.

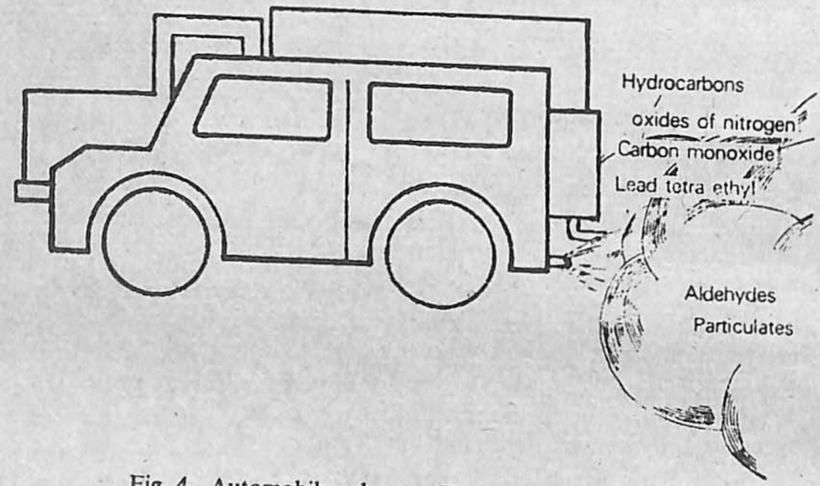


Fig. 4 Automobile exhaust—The major pollutant of air.

Automobiles which have internal combustion engines are the primary transportation sources. Automobile exhausts release smoke and to a certain extent lead particles. As already mentioned smoke is produced primarily from the incomplete combustion of carbonaceous materials. Smoke contains the gaseous pollutants carbon monoxide, hydrocarbons and oxides of nitrogen.

Due to expanding industrialisation and industrial processes, almost all types of pollutants are released into the atmosphere. Cement industries and steel industries, are of great concern because of the difficulty in controlling the emission of pollutants from them.

Solid waste disposal is considered to be a major source of air pollution in urban areas. Backyard burning and open burning of the heaps of solid wastes results in the emission of smoke and gaseous pollutants such as carbon monoxide, oxides of nitrogen etc.

Conventional energy sources are insufficient to supply energy to increasing industries. Further mechanisation of transport and agriculture demands more and more energy. Hence interest has been turned towards nuclear sources. Nuclear materials when released into the air, are potentially more hazardous. Nuclear weapon testings, nuclear reactors, chemical processing plants, research institutions and hospitals contribute many radionuclides to the atmosphere. Out of them, carbon-14, krypton-85, strontium-90, iodine-131 and caesium-137 are of great concern.

Effects of Air Pollution

The effects of air pollution can be studied under the following heads :

1. Effects on human health
2. Effects on animals
3. Effects on plants
4. Effects on materials
5. Effects on atmosphere

Effects on human health

Though the direct cause-and-effect relationships are not established, it has been realised that air pollution is detrimental to human health. Air pollution mainly affects the respiratory system. Both gaseous and particulate pollutants cause severe damage to the respiratory system.

Gaseous pollutants

Carbon monoxide is an asphyxiant gas and when it is absorbed into the lungs, it combines with the haemoglobin in the blood to form carboxy haemoglobin and thus reduces the haemoglobin available to carry oxygen to the body. It is reported that the affinity of carbon monoxide to haemoglobin is 240 times greater than that of oxygen. Persons already suffering from diseases associated with the decrease of oxygen carrying capacity of the blood such as anaemia may be affected quickly, and carbon monoxide may cause even injury to vital organs in such persons. However, carbon monoxide is not a cumulative poison and is excreted or absorbed according to the partial pressure of it in the ambient air and the percentage saturation of haemoglobin.

Sulfur dioxide is the most serious and widespread air pollutant. It has been reported that lower levels of concentration of sulfur dioxide causes temporary spasm of the smooth muscle of the bronchioles. Higher concentration induces increased mucus production. Desqumation or peeling off of the surface epithelium in the mucosa also results with still higher concentrations. The cilia which protect the respiratory system are also affected by sulfur dioxide. The effect of sulfur dioxide in the presence of an inert aerosol such as sodium chloride is much greater than the effect of the gas alone. Sulfur dioxide is also considered to cause cough, shortness of breath and spasm of the larynx. Sulfur dioxide can cause acute irritation to the membranes of the eyes resulting in tears and redness. Moreover, it reacts in the atmosphere to form other undesirable compounds such as sulfuric acid. Sulfuric acid droplets attached to soot particles may pass through the nose and damage the lungs. Sulfur dioxide acts also as an allergenic agent. As it injures the mucosa, the microorganisms chose the injured mucosa as a nidus* for their reproduction and this leads to severe infections and allergic response.

Ozone has been reported to be a strong irritant and it is supposed to reach the lungs much faster than the oxides of sulfur. Even very low concentration of ozone causes pulmonary edema and hemorrhage.

Nitric oxide is a common oxide of nitrogen. It is a non-irritant gas. Nitrogen dioxide is reported to be a pulmonary irritant and excess concentration of this gas may cause pulmonary hemorrhage. Particular evidences on the effects of nitrogen oxides have not been reported.

Hydrogen sulfide and organic sulfides are toxic and they possess a strong odour and create odour problems in the city.

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* Nidus - place in which spores or seeds develop : place for laying eggs for insects and small organisms.

The aldehydes and acids formed are reported to cause eye, nose and throat irritations. Among the aldehydes, formaldehyde and acrolein are the most important. Acrolein also causes irritation to mucus membranes. It also produces bronchio-constriction.

Hydrocarbons are believed to cause lung cancer. Lead emitted from automobile exhausts is a cumulative poison and it is dangerous particularly to children since it can cause brain damage.

Lung cancer, bronchitis, emphysema* and asthma are some of the chronic diseases caused due to exposure to polluted air. Emphysema results in the breakdown and further destruction of the alveolar walls. Alveoli are the sacs within the lungs where actual oxygen transfer takes place. If these sacs are destroyed, breathing becomes difficult. It is reported that in Great Britain, chronic bronchitis is the main cause of death in men in the age group of 40 to 55. Among all the chronic diseases due to air pollution, lung cancer is the most serious one. It is feared that lung cancer is mainly due to the polluted air because;

1. Carcinogens are found in the polluted air.
2. Lung cancer mortality is higher in urban areas than in rural areas.
3. Compounds extracted from contaminated air produce cancer in bio-assay animals.
4. Irritant pollutant affect the protective action of cilia and mucus flow.

In spite of all these reasons, it must be mentioned here that the actual cause-and-effect relationship of lung cancer to pollution has not yet been proved. Chronic bronchitis—another disorder causes excessive mucus secretion in the bronchial tubes is also caused by pollution. In addition to all these chronic diseases, air pollution also causes common cold and pneumonia.

Particulate pollutants

The effects of particulate pollutants are largely dependent on the particle size. The size of particulate pollutants is an important factor. It has a bearing on the penetration of particles beyond the respiratory passages into the lungs. Nasal passages prevent coarser particles larger than 5 microns from entering into the respiratory system. Particles with a size lesser than 5 micron penetrates and enter into the lungs rapidly. The rate of penetration increases with still smaller particles of size about 1 micron. Particles with a diameter of less than 1 micron enter into the lungs easily and rapidly. However, only a small fraction are retained in the lungs.

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* **Emphysema : enlargement of air vesicles of the lungs.**

Of all the matter discharged into the atmosphere, larger sized particles settle more rapidly than the smaller sized ones. The latter particles are reported to be inhaled. Generally aerosols of the size of about 1 micron and less may reach the alveoli of the lungs. The amount of particulate deposition not only depends on particle size but also on other factors such as respiratory frequency and tidal volume. Respiratory frequency denotes breaths per unit time. Tidal volume is the volume moved in and out of the lungs with each breath. Higher respiratory frequencies lessens the percentage of deposition and lower frequencies increases the percentage of deposition. Since residential time for the deposited particles is increased with lower frequencies, the percentage of deposition also increases with lower frequencies. Increase in tidal volume causes a greater volume of air to be inspired and thereby increases the number of particles deposited.

Soluble aerosols will be absorbed into the blood from the alveoli. The insoluble aerosols in the aqueous fluids will be carried to the lymphatic stream. They are reported to be deposited in pulmonary lymphatic depot points or in the lymph glands. Some other insoluble particles which have not been phagocytized* by white blood cells pass through alveolar walls into lymph channels. Some of the deposited pollutants are excreted. Some accumulate in various specific organs and reach a level of concentration at which they exert toxic action. The remaining noxious agents are neutralised by the protective mechanism of the body.

Lead, the most serious pollutant released from automobile exhausts is reported to particularly affect children's brain. It also interferes with the development and maturation of red blood cells. Chronic exposure to lead results in the excretion of porphyrins the precursors

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Phagocytized means the absorption by Leucocytes to prevent infection of the body or simply protection by Leucocytes from infection.

of Haemoglobin, with the urine. Here it must be mentioned that the amount of lead in blood is higher in smokers than in non-smokers.

Beryllium, in the form of its compounds can cause berylliosis. It induces pulmonary granulomatous reaction. Thus beryllium interferes with the diffusion of gases from the lungs to the blood. Finely divided metallic cobalt when inhaled, produces a lung disease which is roentgenographically similar to that due to beryllium.

Other particulate pollutants such as asbestos, silica and some forms of carbon are capable of exerting a noxious (fibrotic) local action in the interstitial areas of the lungs and in the lymphatic tissues. Organic pollutants can cause severe effects, but a detailed discussion of them is beyond the scope of this book.

Radio-active pollutants

A full chapter on "Radio-active pollution" has been devoted in Chapter V.

Air pollution episodes

Our present knowledge on the effects of air pollution mainly comes from the study of acute air pollution episodes. The three most famous episodes occurred in the Meuse Valley of Belgium in 1930, in Donora, Pennsylvania, in the U.S.A. in 1948 and in London in 1952. It is reported that about 60 persons died in Meuse Valley. The number of deaths is about 10.5 times the expected number for an equivalent period of time and season under ordinary circumstances. The Donora episode includes 17 deaths in the community, where only two deaths were experienced normally, in an equivalent period of time. From the mortality records it is found that about 4000 excess deaths occurred, in Greater London, compared with a similar period in previous years during the episode and weeks that followed the episode.

In all three episodes, the pollutants affected a specific segment of the public i.e., those already suffering from diseases associated with the cardio-respiratory system. The worse effects cannot be attributed to a particular pollutant only. The episodes occurred due to the combined action of many particulate pollutants and sulfur dioxide, an irritant gas.

In addition to these episodes, many other episodes also occurred in different parts of the world. Out of them, the episodes at Poza

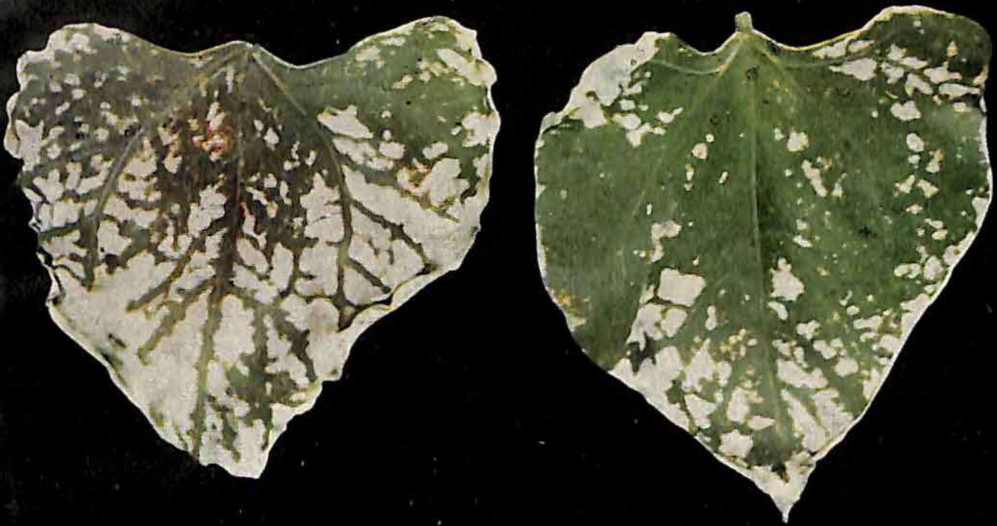
Rica in Mexico and Los Angeles are important. The Poza Rica episode resulted from an industrial accident at a refinery in November 1950. It is reported that about 22 persons died and 320 became ill. The accident at the industry released a large quantity of hydrogen sulfide which spread over the ground around the refinery and crept into nearby homes.

All these episodes are of great concern because they provide significant evidence by which we can evaluate the effects of air pollution on health. Though the laboratory studies reveal much they donot really tell us enough about the effects on man.

Effects on animals

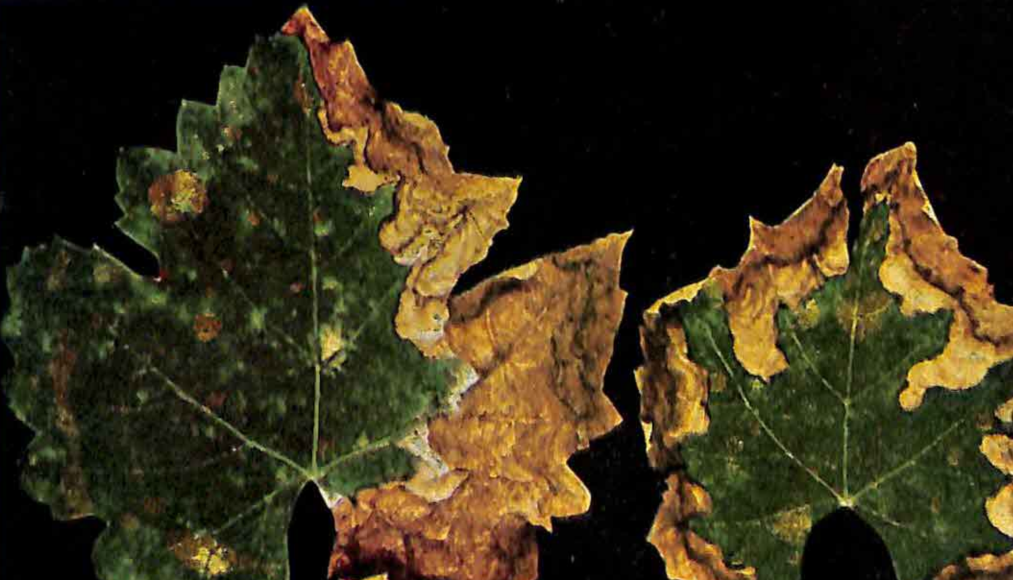
The effects of air pollution on domestic animals are similar to those observed in man. This has been proved by the air pollution episodes that have been documented. In the London episode, it is reported that 5 cattle died and 52 out of 351 cattle became seriously ill. An unknown number of cattle, pigs, dogs, chickens and canaries died or became ill due to the exposure to hydrogen sulfide at Poza Rica. A report about Donora episode indicates that about 20 per cent of the canary population and 15 per cent dogs were affected.

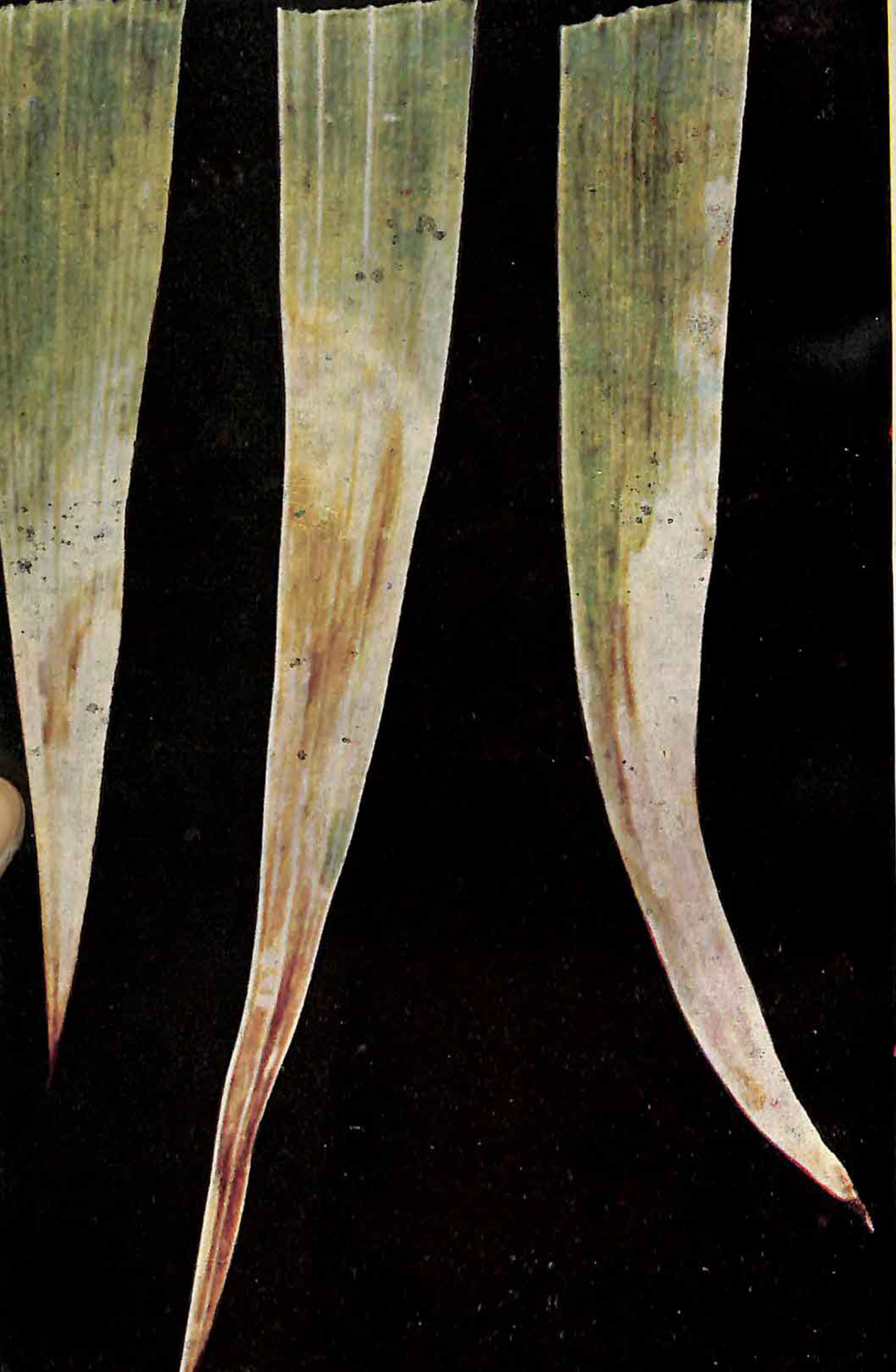
Chronic poisoning results from the ingestion of forage contaminated with atmospheric pollutants. Among the metallic contaminants, arsenic, lead and molybdenum are important. Air contaminated with ozone has irritant qualities and is responsible for pulmonary changes, oedema and haemorrhage in dogs, cats and rabbits. Recent reports indicate however that animals may develop a tolerance to ozone. The other best known pollutant is fluoride. Animals are susceptible to fluorosis, though air borne fluorides do not attack animals directly. When the forage crops contaminated by fluoride-containing materials are eaten continuously by the animals, symptoms of fluorosis appear. Animal fluorosis manifests itself by mottling, staining and pitting of the incisor teeth. Cattle and sheep are the most frequently affected animals. On the other hand, horses and poultry seem to have a high resistance power to fluorides. Since fluorine is a protoplasmic poison, it causes hypoplasia of dental enamel and the intake of higher amounts of fluorine results in an abnormal growth of bones. Bone lesions in animals due to excessive fluorides have also been reported. Diarrhoea,

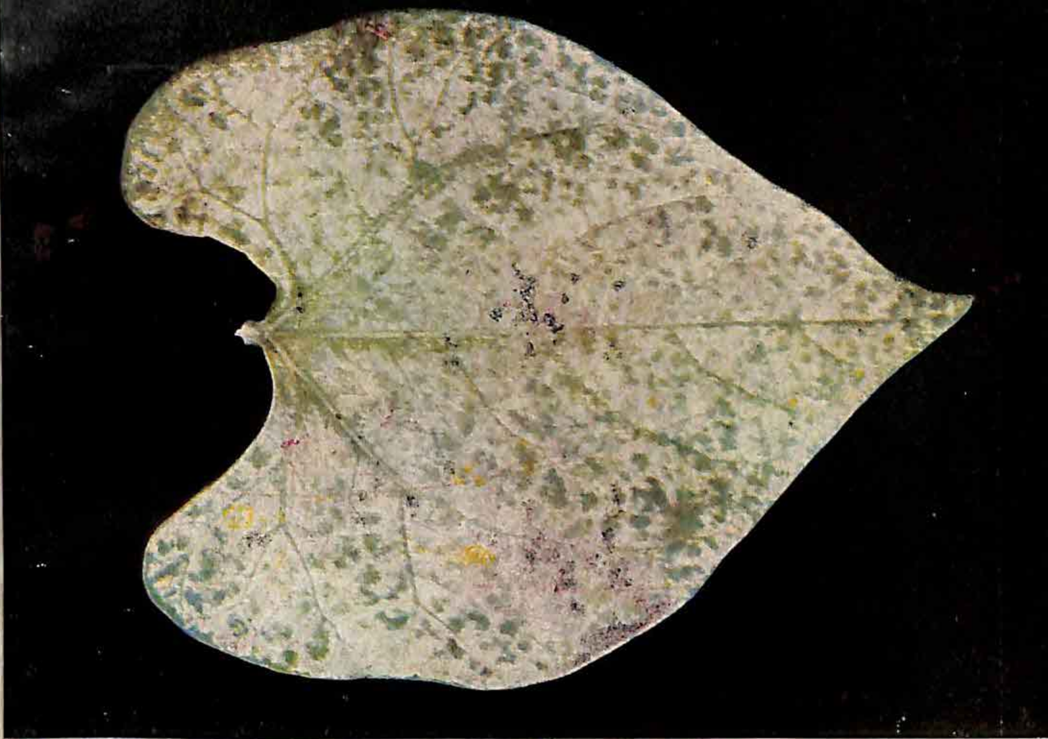


↑ **Plate 1.** Acute sulphur dioxide damage on pinto-bean—upper and lower surfaces of the leaf

↓ **Plate 2.** Fluoride injury on grape leaves



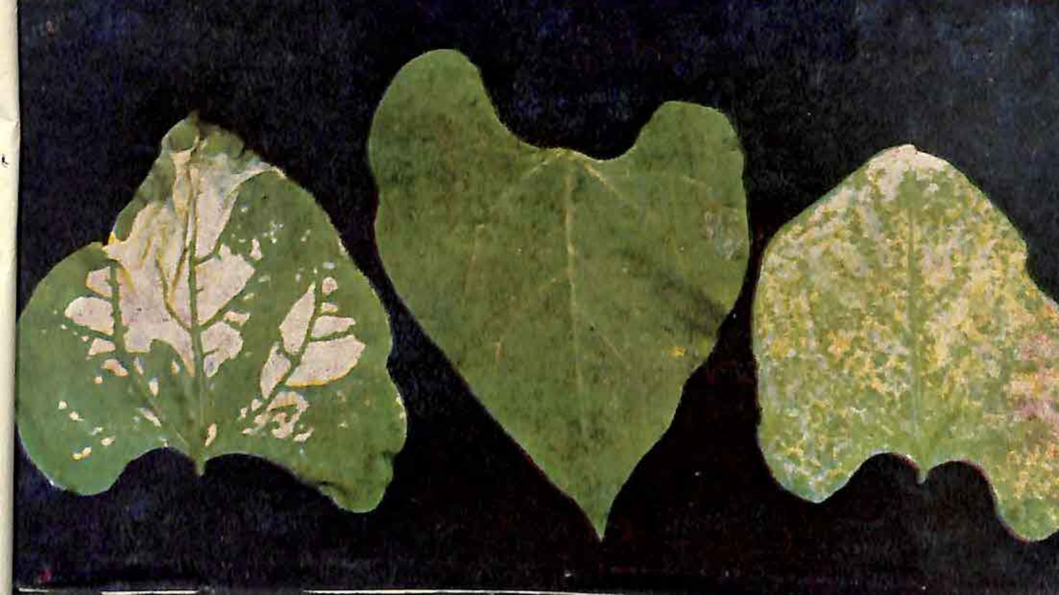




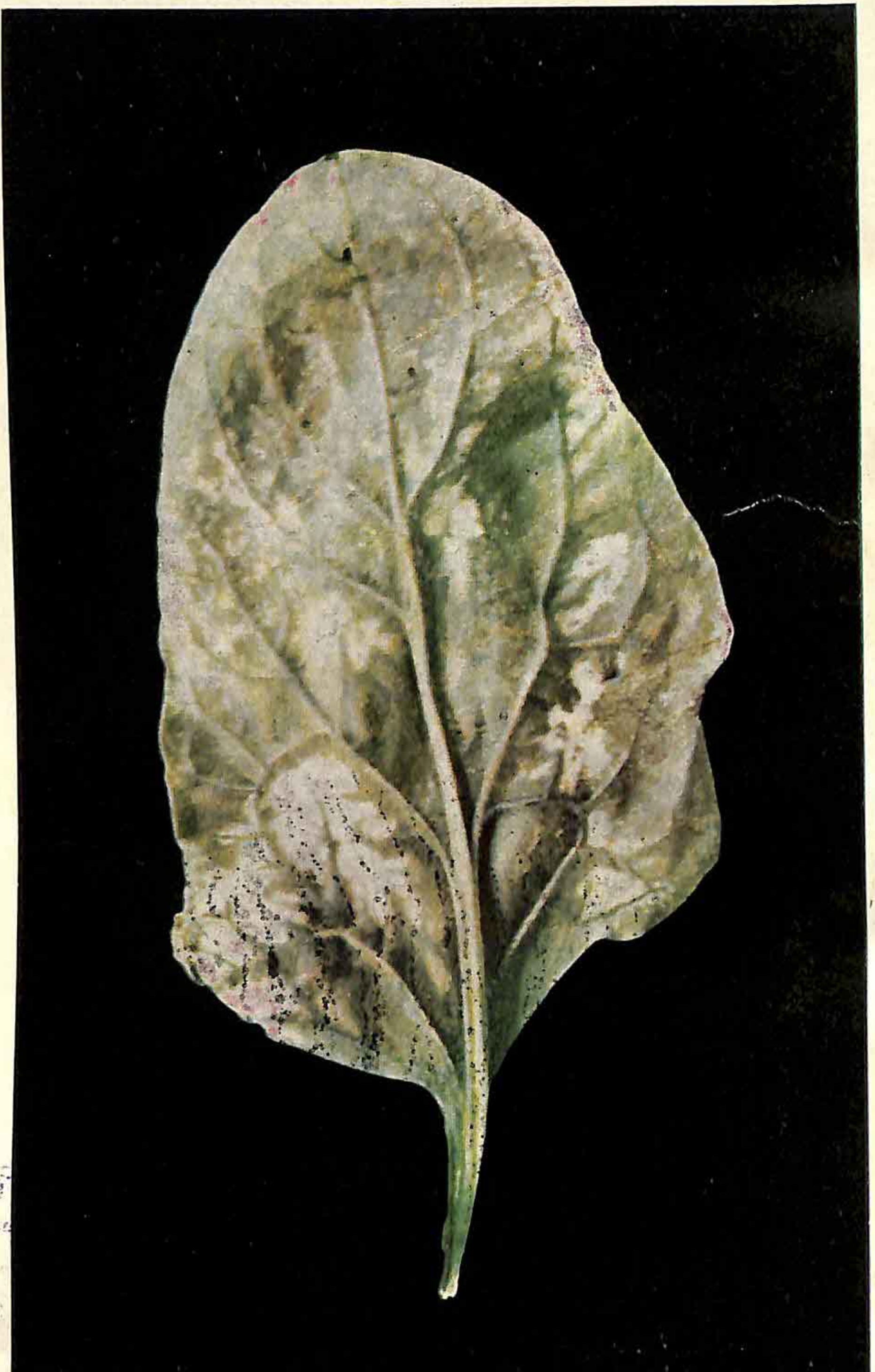
↑ **Plate 4.** Pinto bean leaf with ozone injury

Plate 3. Hydrogen fluoride injury on gladiolus leaves

↓ **Plate 5.** Effect of sulphur dioxide and ozone on the leaves of pinto-bean sulphur dioxide/Control (No pollutant)/ozone



↓ **Plate 6.** Severe lower surface smog damage to spinach



weight loss, lowered fertility, and reduced milk production are some of the other effects of fluorides.

Effects on plants

There are three principal pollutants of prime concern to agriculture—viz., sulfur dioxide, fluorine compounds and smog. The effects of sulfur dioxide are proved clearly beyond doubt. The gas is said to be absorbed through the stomata into the mesophyll of the leaves. When the absorption of sulfur dioxide exceeds a particular level, the cells become inactive and are killed, resulting in tissue collapse and drying of leaves. When only a few cells are injured, that portion of the leaf becomes brownish red in colour or the original green colour becomes bleached. This effect is known as chlorosis. Cotton, wheat, barley and apple are some of the plants most sensitive to sulfur dioxide. In addition to necrosis, (collapse of leaf tissue) and chlorosis, sulfur dioxide also interferes with the respiration and photosynthesis of plants. The toxicity of sulfur dioxide is attributed to its reducing properties.

Acute fluoride lesions on plants are caused by the aerial contamination of fluorides. The lesions have been reported to be similar to that caused by sulfur dioxide. Particulate and gaseous fluorides accumulate on forage to such an extent as to build up concentrations in excess of 30-50 ppm on the inside and outside of the leaves. Leaf-fluoride concentrations of 50-200 ppm usually result in injury. Various types of injuries to plants have been reported and a particular type of injury to maize is reported to consist of a kind of mottled interveinal chlorosis. The leaves of apple, apricot, fig, peach, prune and the members of citracea family are susceptible to injury by air-borne fluorides. It is to be noted, however, that flowers and fruits are more resistant to hydrogen fluoride and other gaseous fluorides.

Fluorides seem to interfere also with the photosynthesis and respiration of plants. This has been proved with the aid of automatic carbon dioxide analysers. Fumigation experiments prove that there is a toxic level of fluorides to plants below which the photosynthesis is not affected and above which it is affected. The fumigation experiments were carried out using hydrogen fluoride as the contaminant and several species were exposed. It is a paradox that some plants are injured heavily even to low concentrations of

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fluoride while some other plants withstand more than a hundred times as much. Another important factor to be remembered is that though the soils contain several hundred ppm of fluorides, plants show little tendency to absorb them.

Exposure to air containing ozone results in the lesions to plants. The lesions are usually confined with the upper surfaces of the leaves. The lesions are characterized by the uniformly distributed white or brown flecks and stipples and irregularly distributed blotches. Ozone flecking is observed with the plants grape, citrus and tobacco.

Smog also causes injury to plants. Smog which contains ozone, peroxy acyl nitrates and other photochemical oxidants is reported to produce early maturity or senescence in plants. A six hour exposure of PAN (peroxy acyl nitrates) concentrations as low as 0.01 ppm is reported to cause injuries to species such as romain lettuce, pinto bean and petunia.

Other gaseous pollutants also cause damage to plants. Chlorine is reported to be about three times as phytotoxic as sulfur dioxide. Ammonia has less phytotoxicity and causes injury to tomato when present in amounts above 40 ppm. Hydrogen sulfide is only slightly phytotoxic and causes slight injuries to radish, tomato, cucumber, soybean, etc. Ethylene has also been reported to cause epinasty and inhibition of nutation in tomato and sweet pea.

Studies on the effects of air pollution provide information on the chemical nature of air pollutants, their concentrations and the duration of exposure to these agents. Hence, in the future it will be possible to use appropriate plant species as alarm signals of potential danger to human health before clinical symptoms are noted. Air pollution studies with reference to plant enzyme systems, indicate informations on similar human enzyme systems and possible human reactions.

Effects on materials

Air pollutants also cause damage to property and meterials. The pollutants most destructive to materials are smoke, grit and dust and oxides of sulfur. Sulfur dioxide is the most damaging of the gaseous pollutants. It changes with moisture and air to sulfurous and sulfuric acids which are more corrosive. Moisture, temperature, sunlight and air movement influence the attack rate of pollutants. Moisture is considered to be the most important without which there would be only little corrosion even in the most severely polluted environments.

Aluminium and aluminium alloys, copper and copper alloys, iron and steel are corroded when exposed to contaminated air. Hydrogen sulfide reacts with lead paints to form lead sulfide thereby producing a brown to black discolouration. Building materials are corroded and disfigured by polluted air in a number of ways in addition to normal weathering. Sooty deposits are said to disfigure buildings by adhesion. During high winds, larger particulates can result in a slow erosion of surfaces. Since the oxides of sulfur react with limestone to form calcium sulfate, a slow loss of substance occurs in rain-washed areas and an unsightly blistering occurs in more sheltered areas. Though the damages caused by air pollution to materials are not so serious, aesthetic considerations make air pollution a nuisance.

Effects on atmosphere

Increased combustion of fossil fuels and oil, increases the carbon dioxide concentration of the atmosphere in recent years. Though carbon dioxide is not considered as a pollutant it has its effects on the atmosphere. Carbon dioxide absorbs heat strongly and the radiative cooling effect of the earth is thus decreased. Calculations show that the present amount of carbon dioxide will be doubled in the future resulting in an increase in the temperature at the earth's surface by about 1.3°C.

In contrast to the rise in temperature produced by carbon dioxide, dust particles reduce the temperature of the earth's surface. The dust particles released into atmosphere become the nuclei for water vapour to condense or freeze to form rain. As a result the skies become more cloudy. Moreover solar radiations are screened directly by dust particles to enter into the atmosphere. Hence, a relative decrease in the temperature of the atmosphere is resulted. It is reported that about 10 per cent increase in atmospheric turbidity causes a decrease of 0.8 per cent in the total amount of energy absorbed by the atmospheric system which would result in cooling of the climate by about 1°C.

Air Pollution : Measurement of Air Quality

To evaluate the actual pollution of air, measurement of air quality is necessary. Measurement of air quality is complicated by the lack of sufficient information regarding what constitutes "clean air" and because of the difficulty in defining "quality". To make the measurement more perfect, sampling should be done perfectly. Samples should be representative whether they are taken at the source or from the ambient atmosphere. The best results can be obtained, only if standard analytical techniques are used. The potential for air pollution must be studied in relation to the dispersive properties of the atmosphere.

The examination of air quality includes the following three measurements—

1. Emission measurements: This is also called "stack sampling" when a stationary source is analysed. Sampling in mobile sources is more difficult. In stack sampling, a hole is punched into the stack and samples drawn out for analysis on the spot.
2. Ambient air quality : The quality of ambient air is of prime importance. All evidence of health effects are based only on these measurements.
3. Meteorological measurements : It is necessary to know the meteorological parameters so as to know how and why the pollutants travel from the source to the receptor.

Since varied types of changes in concentrations occur due to weather situations, other deductions become less certain, if meteorological parameters are not available.

Measurement of air quality comprises of sampling and analysis which are discussed briefly in the following pages.

Sampling

Sampling constitutes the main part of the examination of air quality. There are many factors to be remembered before sampling. The size of the sample is an important factor. It should be big enough to make the analysis possible and more perfect. Another factor to be remembered is the change that occur in the sample during and after sampling. Many substances when present in low concentrations can exist without any internal reaction. If the sampling is prolonged, the contaminants may react internally to form some other products which would either be present in the waste gases or in the atmosphere. Hence there are many chances for an analyst to err and these facts should be borne in mind.

Sampling of particulate contaminants

In order to minimise errors sampling should be done as far as possible under isokinetic conditions. The gas stream carrying particulate contaminants should never be disturbed before entering into the collecting device. Deposits and condensations should not be allowed to form on the walls of the sampling vessel.

Sampling of waste gases

There are so many difficulties encountered in this type of sampling. However, it is advised that the gas stream should be sampled at various points and large number of samples have to be taken.

Sampling in the open air

Numerous difficulties arise when sampling is done in the open air. To minimise errors and to account for the difficulties, continuous recording instruments may be employed. Several instruments have to be placed simultaneously at various points in the area. Simultaneous meteorological measurements are also necessary. Further, the topographic and orographic* features have to be studied in order to integrate all sampling data.

Devices and Methods for Sampling

Devices and methods for sampling particulate contaminants : For the collection of particulate matter, sedimentation methods, filtration methods, thermal precipitation methods, electrostatic precipitation methods, visual and photometric methods may be employed.

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* Orographic — Branch of physical geography dealing with mountains.

Sedimentation is a very suitable method for sampling suspensions of pollen. The principle underlying thermal precipitation method is that hot surface repel particles suspended in the air, and the repelled particles will be collected on cold surfaces. Electrostatic precipitation methods consist of the submission of the gas stream to the action of suitable electric field such that deposition of particles in suspension on electrodes occur. The devices that operate by visual and photometric methods are used for direct observation of the state of dispersion of the particles in the air or in a waste gas. The Ringelmann cards are an example of a visual method. (Readers are advised to refer *Air Pollution Technology* by D.E. Painter, 1974 for further details regarding this method.)

Devices and methods for sampling gaseous pollutants : Samples of gases and vapours may be collected using absorbers, adsorbers and condensers. By selecting the suitable absorbent solutions it is possible to absorb even minute traces of many gases and vapours. Among the contaminants analysed by this method, oxides of sulfur, oxides of nitrogen, hydrogen sulfide, hydrochloric acid, hydrofluoric acid and ammonia are important. Adsorption is brought about by aspirating the air or gas through adsorption columns which may contain silica gel or activated charcoal or any other suitable adsorbing material. Adsorption is particularly used for the estimation of ozone and light hydrocarbons. The gas or air collected in the container is cooled in the condensation procedure. Condensers are employed for sampling odoriferous substances.

Sampling of radioactive materials : The sampling of radioactive materials is almost the same as that for other pollutants. Rainfall may be collected in jars and its radioactivity may be measured. On the other hand, high-volume samplers may be employed to collect the air-borne radioactive dust on a suitable filter and evaluated with a Geiger-Muller counter.

Analysis

In order to understand the analytical aspects better, the analysis of atmospheric samples may be divided into three basic groups as follows :

1. Chemical methods,

2. Instrumental methods, and
3. Biological methods.

Chemical Methods

Quantitative methods of chemical analysis can further be subdivided into volumetric methods, gravimetric methods, colorimetric methods, chromatographic methods and nephelometric and turbidimetric methods.

Volumetric methods include acidimetric and alkalimetric methods, oxidation and reduction methods and precipitation methods. Acidimetric and alkalimetric methods are used for the estimation of acid and basic substances such as sulfurous anhydride, ammonia, etc. Chloride, aldehydes and oxidizing agents are determined by oxidation and reduction (iodometric) methods. Hydrofluoric acid, hydrochloric acid and hydriodic acid are determined by precipitation methods.

Gravimetric methods are employed in the determination of sulfur dioxide, dust, soot and other particulate matters dispersed in air.

Colorimetric methods are best suited and widely employed for the estimations of metallic vapors, dusts, oxides of nitrogen, ammonia, fluorine, chlorine, carbon monoxide, hydrogen sulfide, carbon dioxide, formaldehyde and many other organic or inorganic compounds.

Nephelometric methods and turbidimetric methods are useful in assaying gaseous and particulate matters. The advantage of these methods is that only smaller volumes of sample are enough. Now-a-days chromatographic methods are used extensively by which the separation and identification of many substances are possible.

Instrumental Methods

Instrumental methods are finding an ever increasing application because of the extreme rapidity with which analysis can be carried out. These methods are efficient where the classical methods fail to give satisfactory results. Absorption spectrometric methods, emission spectrometric methods, mass spectrometric methods, X-ray diffraction methods, polarographic methods, microscopic methods, thermal conductivity methods and refractometric methods are some of the instrumental methods.

Spectrophotometric methods based on the absorption in the visible spectrum is employed both in gaseous and particulate matter estimations. Emission spectrometric methods are employed for the identification of the elements present in particulate matter particularly for sodium, potassium, calcium, beryllium, lead, antimony and cadmium. X-ray diffraction methods are suitable for the qualitative and quantitative analysis of crystalline substances such as mineral dusts which are present as a suspension in the atmosphere. Microscopic methods are used for the identification of particles for the determination of particle size. Microscopy is sometimes combined with the chemical procedures for the preparation of precipitation samples.

Biological Methods

Analysis of vegetation and of the body fluids of animals bred in the contaminated area, helps in the identification of pollutants. Some of the pollutants can also be detected by their organoleptic properties, e.g. odour. However, biological methods have only limited applications.

Prevention and Control of Air Pollution

Prevention of air pollution is not so simple as explained in words. It is impracticable to provide at reasonable cost all the growing needs and amenities of modern life without causing some pollution of the air. However, much of the pollution could be prevented without undue cost by careful planning and siting of industries, better design equipment and better operation of the equipment. There are three major means of controlling pollution. They are :

1. Fuel selection and utilization,
2. Process changes or epuipment, and
3. Site selection and zoning.

Control of Air Pollution by Fuel Selection and Utilization

The primary fuels used are coal and oil. Smoke, grit and sulfur dioxide are the major pollutants from the combustion of these fuels. It is to be mentioned that though the combustion of both coal and oil can be controlled to prevent smoke, the control is generally easier with oil than with coal. Moreover the danger of emitting smoke is greater with smaller installations than with larger ones when coal is used as a fuel. To eliminate these effects, oil can be used instead of coal. But, however, the amount of sulfur dioxide emitted is higher with oil. Hence, substituting coal with oil is not sufficient to prevent smoke. Further, the quantity of oil needed will then be greater. Therefore, other methods have to be adopted.

Modern power stations and industries largely use coal as a fuel. The coal used is varied in composition. The variable properties include chemical composition, volatile content and the caking properties. These properties affect the combustion to a considerable extent. In order to control smoke production, the coal is pulverized and then used. However, there remains the problem of grit emission. Irregularities in the fuel bed result in an inefficient combustion. Combustion efficiency is increased now-a-days by replacement of hand-firing with mechanical stokers. Mechanical firing results in some selectivity in choice of coal. When oil is used as a fuel, it is essential that the ratio of air to fuel should be maintained so as to provide only a slight excess of air over that required theoretically for complete combustion, in order to prevent smoke emissions. When coal tar is used, the same measures used for oil burning should be adopted. The main factor that affects the combustion of coke is its size. Hence the size must be considered while selecting a suitable coke-burning appliance.

Control of air pollution by process changes or equipment

This can be broadly divided into two categories. These are :

1. Control of aerosol emissions and
2. Control of gaseous pollutants.

Control of aerosol emissions

Newer equipments have been designed at present to control aerosol emissions. They can be classified as (i)) arresters and (ii) scrubbers.

Arresters : Arresters can further be classified into three subgroups : (a) inertial separators, (b) filters and (c) precipitators.

Inertial separators : This category includes all dry-type collectors which make the inertia of the dispersoid to effect particulate-gas separation. Two types of equipments are now in use. They are cyclonic separators and trajectory separators. The cyclone separator is one of the least expensive and most important types of dispersoid collector. It produces a continuous centrifugal force which exerts greater inertial effects of the dispersoid. Cyclonic separators have been widely employed for industrial dust collection. They are used for the control of gas-borne dispersoids in the industrial processes such as manufacture of cement, mineral processing, paper and pulp industries, feed and grain processing and wood working industries.

Filters : To collect extremely fine particulates, filters can be employed which in no way, affect the conditions of temperature and humidity. Initially it is developed to remove solid dispersoids from the carrier gas by "filtration" of the gas through a porous medium such as cloth or fibre. Next to cyclonic separators, filters constitute the most effective means of controlling atmospheric pollutants.

Precipitators : The electrostatic precipitator is considered to be the most effective device for preventing the emission of dust from fuel gases and is the standard equipment for large power stations. The basic principle is to pass the dispersoid-laden carrier gas between two electrods to which an unidirectional high voltage potential is applied. The radius of curvature of one electrode (discharge electrode) is many times smaller than that of the second electrode (collecting electrode). Owing to the greater differences in potential and radius of curvature, a corona discharge is established in the region of the discharge electrode resulting in a powerful ionizing field. Consequently the dispersoids in the carrier gas become charged and migrate to the oppositely charged collecting electrode. After deposition, the particles can conveniently be removed by mechanical processes.

Scrubbers : These are the least used devices for removing particulate matter since these are better suited for the removal of gases and vapours. The scrubbers may be classified as wet washers, impingement scrubbers, gravity spray towers, cyclonic scrubber, disintegrator scrubbers, and spray de-dusters.

Control of gaseous pollutants

The techniques employed for the removal of gaseous pollutants differ markedly from that of aerosols. Control equipment can be classified as combustion, absorption and adsorption equipment.

Combustion is applicable to pollutant gases which are oxidizable. The pollutants are exposed to a high temperature (650°C) in combustion process. Petro-chemical industries, fertilizer industries, paint and varnish industries advantageously use combustion type control equipment. It has to be mentioned. however, that their cost is high.

Absorption is a diffusional process in which a transfer of gas molecules into a liquid phase takes place. An absorbent should have a greater absorbing capacity without build-up of considerable back pressures. The absorption equipment is classified as spray chambers, packed towers and bubble cap or sieve plate contractors. The spray chamber consists of an empty chamber in which the gas is allowed to pass through curtains of liquid spray. In packed towers, the absorbent flows downwards through a bed of packing material, while the gases move upwards and an intimate contact between absorbent and gases occurs. In bubble cap containers gases pass upwards through a series of plates on which absorbent exists.

Adsorption is the only means in controlling air pollution which occurs due to some gases and vapours and inflammable compounds which cannot be treated or removed by other means. Adsorption is a surface phenomena and it needs the presence of large solid surface areas. Toxic and odoriferous compounds are reported to be efficiently removed by adsorption.

Control of emission from Motor Vehicles

The automobile exhausts deposit in air hydrocarbons, carbon monoxide and oxides of nitrogen. In the presence of sunlight, photochemical reaction takes place between certain hydrocarbons and oxides of nitrogen to form secondary pollutants. Emissions are reported to occur from the crank-case also.

At present many techniques for the control of emission have been developed. These techniques include tune-ups, catalytic reactors and engine modification. A tune-up is one which has a significant effect on emission compounds. For example, a high air-fuel ratio will reduce the concentrations of both carbon monoxide and hydrocarbons. The catalytic reactor is reported to oxidise carbon monoxide to carbon dioxide and thereby oxides of nitrogen are converted to nitrogen. However, catalytic reactors have some disadvantages. They oxidise the sulfur present in the fuels to sulfur trioxide and secondly they are easily fouled by lead. Engine modifications have some marked advantages. The modified engines are said to contain two compartments in the cylinder by which a broad flame is produced for efficient burning of the fuel. However, these changes are not sufficient.

Reduction of concentrations of sulphur dioxide

At present, there are no satisfactory methods to prevent the emission of sulfur dioxide from the burning of sulfur bearing fuels. Hence, very high smoke stacks are built to ensure adequate dissipation of the sulfur dioxide and an adequately low concentration at ground levels. In order to protect human health, power stations are constructed far from towns in some countries. Researches are conducted throughout the world to develop methods by which sulfur dioxide in fuel gases can be absorbed without any cooling of the gases (so that the rise of the plume is not adversely affected).

Control of air pollution by site selection and zoning

Site selection is the process of locating a single industrial plant. Site selection results in the production of a single source of pollution as compared with numerous emission sources. Zoning is a control measure based upon the knowledge of the mechanics of the atmosphere, which acts as the transfer medium. Siting of factories and dwellings and zoning of areas should take into account meteorological conditions, particularly micro meteorological conditions. However, other factors also come into picture. Hence in selecting a site an industrialist must take into account the factors such a facilities for the supply of raw materials, transport, labour and markets for products.

Legal Controls*

Technical and scientific knowledge alone will not be sufficient in controlling air pollution. The cleansing of air is possible only by legal applications of technical knowledge. As suggested by the

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World Health Organisation, the administrative control of atmospheric pollution can be most effectively developed into appropriate laws at a national level through the action of a committee of persons representing public health administration, industrial hygiene, fuel usage, agriculture, science, industry and town planning. Such a committee would recommend the necessary legal instruments suitable to its unique country problem. Further, WHO ensures that such a committee could call upon WHO for guidance. It is also suggested by WHO that the legislation should be directed towards :

(a) The control of sources of pollution by specifying the types of industrial and other processes which should operate under supervision by control authorities, and the types of emission which should be kept to a minimum ;

(b) the institution of town-planning practices in which due attention is given to the planning and zoning of industrial sites for the purpose of reducing air pollution, providing always that such action does not make the conduct of industry prohibitively costly or even impossible ; and

(c) the provision of regulations controlling the types of fuel to be burned in installations where combustion emissions are not otherwise controllable.

Conclusions

On the basis of existing knowledge, much pollution of the atmosphere could be avoided without undue capital expenditure. Certain emissions from special processes, however appear to be unavoidable with present techniques, and others can be reduced only at great cost. Intensified research is needed to obtain more information on methods of significantly reducing the quantity of pollutants discharged from special processes.

III

Water Pollution

WATER POLLUTION may be defined as the adverse change in composition or condition of the water such that it becomes less suitable for the purposes for which it would be suitable in its natural state. The changes include, physical changes, chemical changes and biological changes. Water pollution now-a-days is considered not only in terms of public health but also in terms of conservation, aesthetics and preservation of natural beauty and resources.

Sources of water pollution

The sources of water pollution are numerous. Most industrial effluents are discharged into rivers. They contain both organic and inorganic hazardous materials and non-biodegradable materials. These industrial effluents when discharged through sewage system will poison the biological purification mechanisms of sewage treatment and these sewages on subsequent discharge will result in pollution of rivers. Otherwise when the industrial effluents are discharged directly they are injurious to public health. Another important industrial waste is heat. Heated effluents can drastically alter the ecology of a stream or lake. This will be further discussed in later pages.

The next principal contributor is municipal sewage. Most municipal sewages are reported to receive no treatment before discharge. These in combination with industrial wastes produce newer public health problems. It is a point to be noted that since population growth is increased the quantity of waste water is also increasing in addition to the production of large quantities of sewage. All the sewage contain decomposable organic matter and they exert an oxygen demand on the receiving waters. Treatment of sewage deposits the suspended materials at the bottom known as sludge and the liquid waste contains ions such as sodium, potassium, calcium, ammonium, manganese, chloride, nitrite, nitrate, bicarbonate, phosphate and sulphate in dissolved condition. The common organic materials found in a sewage are soaps, synthetic detergents, fatty acids, esters, proteinaceous matters such as amines, amino acids, amides and amino sugars. In addition to the above components it also contains numerous micro-organisms some of which may also be pathogenic in character.

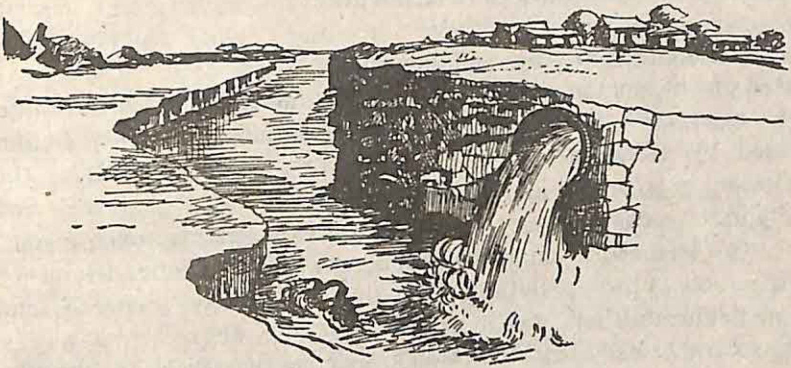

Fig 5. Sewage makes the water foul and filthy.

Next in order is the waste from agricultural practices. Drainage from silage and manure slurry from intensive husbandry is reported to cause heavy pollutions of some water courses. Plant nutrients, insecticides and pesticides are also introduced into water courses by agricultural practices. Sediment from land erosion containing mostly inorganic materials is also classified as a pollutant.

Underground water pollution occurs by the substances leached from refuse and spoil heaps, from fertilizers spread over the land and from silage making. The pollution of water may also arise from the disposal of industrial wastes in disused mineshafts and quarries. It is deemed that the pollution affecting underground aquifers is more serious than it would be in a surface water course, due to the impossibility of treatment of the polluted water. Since saline waters are drawn into the aquifer, overpumping in coastal areas is considered to cause ground water pollution.

The various sources that cause pollution of coastal waters arise from the discharge of sewage and industrial effluents, discharge of sewage and rubbish from ships, transportation of oil and exploration and exploitation of the sea-bed and ocean floor. However, the tendency of self-purification of the sea is high due to different factors such as dilution, temperature etc., and pollution of the sea is not considered as serious as river pollution.

Nature and effects of water pollution

Based on the contaminants, water pollution may be divided into two types, (i) pollution caused by materials and (ii) pollution caused by biological organisms. The first category involves the following organic and inorganic contaminants. Acids, alkalis, carbohydrates, coal, dyes, fats, soaps, waxes, gases, toxic metals, oils, proteinaceous matters, resins, rubber, synthetic detergents, and various other pollutants including radio-active materials and heated effluents that impart thermal loading on receiving waters. The second category includes biological organisms such as bacteria, viruses, plants and animals.

Acids: Both organic and inorganic acids are discharged commonly to rivers in the form of industrial effluents. The principal processes which contribute mineral acids are manufacture of chemicals, manufacture of fertilizers, battery manufacture, electro-plating, manufacture of DDT, viscose processing, brewing, textiles, mining, iron and copper pickling. Organic acids are discharged from the manufacture of rayon, fermentation plants, distilleries, dyeing industries, manufacture of leather, chemical industries etc. Since organic acids are mild, they are given less importance regarding pollution aspects and only inorganic acids are studied carefully due to their toxic nature. The main constituent of acid wastes are sulfuric acid. In addition to this, nitric acid, hydrochloric acid and phosphoric acid are also seen.

These acids are considered to cause damage to metals or concrete structures, pumps etc. by their corrosive activity. Moreover, they produce hydrogen sulfide gas when they come into contact with the sludge and mud of the river. The lower the pH value, the greater is the amount of hydrogen sulfide liberated leading to a higher degree of atmospheric pollution. Acidic pollutants, also destroy micro-organisms and thus inhibit self-purification of the stream. Fish and other aquatic animals are adversely affected by a sudden change in pH conditions of the river. The sudden change may be on the acid side or alkaline side. Acids are reported to be lethal to fish and other forms of aquatic life.

Alkalis : Alkalis also cause damage to rivers and streams by altering the pH values resulting in a break in the natural buffer system. Chemical manufacturing wastes, kier liquors, wool scouring wastes, tannery wastes, cotton mercerising wastes are the principal contributors of alkalis. The alkali wastes raise the pH values even up to 12. Alkalis behave similarly as acids in destroying bacterial and other micro-organisms so as to inhibit the self-purification of a stream. Fish and other aquatic life are also affected by the sudden rise in pH. Strong alkalis are reported to produce asphyxiation by the coagulation of gill secretions in fish. Alums and other aluminium salts have a similar action due to the hydrolysis followed by formation of hydrogen ions.

Coal : Coal is a common substance and is found in the effluents of coal-washing plants in finely divided form. Coal acts in the same way as that of suspended matter and hence is discussed elaborately under the heading "Suspended Matter."

Dyes : Now-a-days thousands of dyes are prepared and they find their way into the streams through the discharge of effluents from dyeing and printing industries, textile industries, and to a lesser extent from paper and ink manufacturing industries. These dyes are prepared from coal-tar hydrocarbons such as benzene, naphthalene, anthracene, toluene, xylenes etc. Apart from the effluents containing chromium and iron, these dye effluents are the only effluents that impart colours to the water. These organic dyes impart colours even when present in micro-quantities. Though the dyes are not harmful, they create aesthetic problems. Morever they also adds to the B.O.D. (Biochemical Oxygen Demand) of the water. In addition to the dye material, salts of chromium and aluminium, and iron which are used as mordants are also found in dye effluens. These mordants also impart colour. The colours imparted to water may be removed by treatment with activated carbon or other chemical agents.

Fats, soaps and waxes : Fats are the animal and vegetable oils. Fats are insoluble in water but soluble in organic solvents such as ether, chloroform etc. Fats and soaps are discharged from wool scouring processes, oil and fat refining processes, soap manufacturing process and laundering processes. Fats, the higher fatty acids undergo decomposition to lower fatty acids when subjected to microbial action. These lower fatty acids produce unpleasant rancid odours.

Soaps have their common occurrence in sewage, laundry wastes and textile wastes. Soaps are the metallic salts of the higher fatty acids. Both sodium and potassium soaps are soluble in water while the soaps of calcium, aluminium, manganese, lead and zinc are insoluble. Sodium and potassium soaps are used for domestic purposes and other metallic soaps are used as industrial soaps.

Waxes comprise both natural and synthetic waxes. Waxes are found in the wastes from wool scouring process and in the effluents of paper and textile industries. They are the esters of higher fatty acids.

Gaseous pollutants : This category includes ammonia, free chlorine, hydrogen sulfide, ozone and phospine. Ammonia is liberated during the manufacture of chemicals, fertilizers, gas and coke. Sewage and other nitrogenous organic matters contribute and increase the ammonia content to dangerous levels. Free chlorine results from the processes of textile bleaching, paper mills and laundries. Hydrogen sulfide occurs by the bacterial action and pH alterations during the discharge of viscose rayon wastes, and sulfate and sulfite containing materials. Inhalation of considerable quantities of ammonia produces a spasm of the glottis and it may also lead to death. Ammonia seems to be an internal poison to fish which gets into the body through the gills. According to Ellis* the maximum permissible concentration of ammonia is 2.5 ppm above which it is lethal to fish. The presence of excess amount of free chlorine in streams or rivers has to be avoided because of the following reasons :

i) Free chlorine is a powerful irritant.
ii) It causes fatal pulmonary oedema, a disease of the lungs in man.
iii) It completely destroys the aquatic life including fish.
iv) It is corrosive to matals, building structures etc.

Sewages containing organic sulfur compounds are decomposed by sulfate reducing bacteria and proteolytic bacteria to form hydrogen sulfide in the absence of oxygen. The hydrogen sulfide formed is further converted into sulfuric acid which corrodes concrete structures. In warm climates formation of hydrogen sulfide is enhanced and severe corrosion seems to occur. In addition, it causes discolouration of lead paints and of copper and brass on boats.

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* M. M. Ellis, "Detection and measurement of stream pollution", Bulletin No : 22, U. S. Bureau of Fisheries, Washington, 1937.

Apart from all this, hydrogen sulfide causes odour nuisance. It has an obnoxious and strong smell. Most of the odour nuisance of rivers and stream arises due to the presence of sulfides only. Even in a concentration of 0.001 ppm, hydrogen sulfide exhibits a characteristic rotten egg smell. The extent of odour nuisance depends on the pH value and the amount of dissolved sulfide present in the water. The liberation of hydrogen sulfide is inversely proportional to the p H value.

Hydrogen sulfide is a local irritant and acts as a respiratory depressant causing conjunctivities, bronchial irritation and oedema of the lungs in man. It has a similar effect to cyanides in that both these inhibit oxygen utilisation. The approximate toxic concentration of hydrogen sulfide to fish has been fixed at 0.5 to 1.0 ppm above which it is lethal to fish.

Ozone is reported to be highly toxic to fish and its toxic concentration ranges from 0.1 to 1.0 ppm. Anaerobic break down of organic phosphorus compounds results in the formation of phosphine. The toxic concentration of phosphine to fish is about 3.6 ppm.

The other minor gaseous pollutants are carbon dioxide and carbon monoxide. Free carbon dioxide is produced by the action of acid discharges on bicarbonates or by the oxidation of organic matter. Free carbon dioxide is lethal to fish and its eggs. Carbon monoxide is present in the effluents from gas works and it interferes with the respiration of fish.

Pesticides : Pesticides have great value in the control of insect-borne diseases affecting man and in the protection of crops and livestock. They are used in homes, industries, and shops and by farmers, gardeners and foresters. In agriculture, these chemicals are used to protect plants against disease and pests, and to treat seeds. All biocides have developed during the past 30 years only. Though these biocides contributed much to mankind, the use of some of them are restricted because of the dangers to the natural environment. Organochlorine compounds (chlorinated hydrocarbons) and organophosphorus compounds are two important classes of biocides. Organochlorine compounds are more toxic than organophophorus compounds. DDT, (2, 2-bis-p-chloro-phenyl) 1, 1, 1 trichloroethane

BHC (gammaexaner-hexa or lindane), Aldrin (Hexa chloro-hexa-hydrodimethano-naphthalene), parathion (O,O-diethyl O,p-nitrophenyl thiophosphate), TEPP (Tetra ethyl pyrophosfate), Toxaphene (chlorinated comphene) are some of the important insecticides and 2,4-D (2,4-dichloro phenoxy acetic acid) and Santobrite. (Sodium pentachlorophenate are some of the important herbicides). All biocides behave similarly to DDT and a study of DDT holds good for all biocides. DDT is the most widespread man-made molecule in the environment. DDT, the archetypal pollutant is considered to be the most emotive and controversial of pollutants. DDT is partially soluble in water and it evaporates into air resulting in atmospheric pollution. Winds, rains and rivers are the carriers of DDT to all over the planet. The DDT from air and water accumulate in animal tissue, humus, soil or mud in concentrations thousands of times higher than it is found in water through food chain. Man is also contaminated by DDT and other organochlorine pesticides residues. The levels of these insecticides inhuman fat is reported to be on the lower side. DDT is fatal to fish, crustaceans and shell-fish. Some organisms are extraordinarily sensitive even to very low concentrations of DDT.

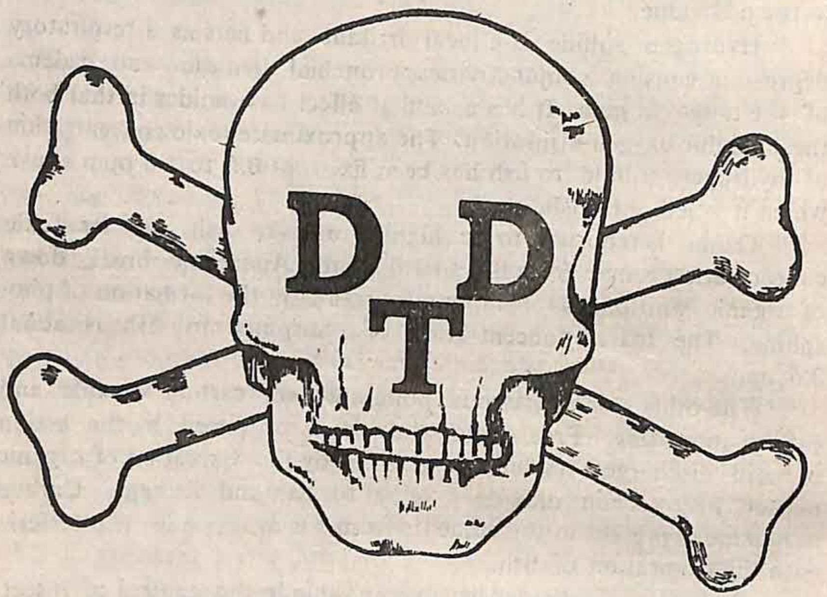

Fig. 6 : DDT—in every corner of the earth.

For example, one part DDT per trillion seems to cause death in brine shrimps. The foremost danger of changing of behaviour or metabolic activities of the body arises from DDT. Laboratory studies indicate that DDT causes depression of photosynthesis in planktons. It makes fish unable to tolerate low temperatures. It causes birds to lay thin shelled eggs. Even the raptorial hawks and falcons are affected by DDT. DDT causes death and breeding failures in them.

The residues of DDT in soil disappears slowly and the period is estimated to be roughly about fifteen years. It is reported that DDT is continuously recycled in living systems. Other insecticides such as gammexane, aldrin, dieldrin, endosulfane and chlordane are also reported to be similar in causing effects to wild life and in changing the metabolic activities through the change in body chemistry.

Fertilzers and farm wastes

Modern agricultural practices introduce fertilizers into water. The surplus of fertilizer not taken up by the crops are washed from land into rivers and lakes. Now-a-days, the use of fertilizer is increased by a number of times. These fertilizers are generally retained in the soil and by the crops, but some nitrates are liable to be washed out due to the negligence in applying fertilizers to arable lands, particularly in a wet spring. These nitrates cause undesirable effects on rivers and lakes. Increase in the population of cattle and pigs has resulted in an increase in the numbers of cattle sheds. Poultries have also increased considerably. Buildings in which cattle and pigs are housed are commonly hosed down with water for cleaning with the result that the manure is washed out and deposited as wet slurry on the land. This slurry deposited on soil may be washed or it may seep into drains and streams causing pollution in them. These manures are completely organic in nature. The quantity of organic material produced by cattle and pigs is high. It is reported that a cow can produce as much organic material as sixteen people and a pig as much as three people. Faecal matter is mainly constituted with phosphates. Excess amounts of nitrates in conjunction with phosphates cause many unwanted nuisances. For example, when the amount of phosporus (as phosphate) and nitrate nitrogen exceeds one part and thirty parts per hundred million parts of water eutrophication may occur and the whole stretch of water may become choked and the plants may rot and fish will die due to depletion of oxygen. The control of nitrate seems to be more difficult according to recent reports.

Toxic metals : Mining processes, discharge of industrial effluents containing metallic solutions, dumping of solid wastes which contain metal salts and some agricultural practices such as the use of mercury based biocides introduce toxic metals to water courses. Battery manufacturing industries, paint manufacturing industries, electroplating industries, viscose-rayon manufacturing industries, copper pickling industries and galvanizing and rubber processing industries are some of the important industries the effluents of which contain considerable amounts of heavy metals. The primary metals considered to be toxic are lead, arsenic, copper, cadmium, mercury, and nickel.

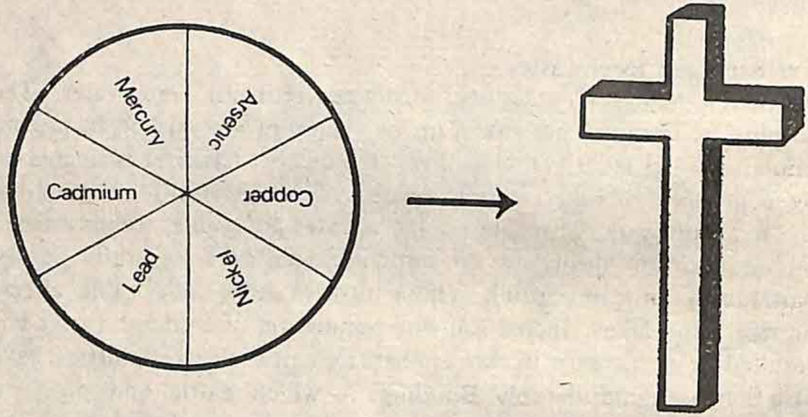

Fig. 7 : Metals are the indestractible poisons

These metallic solutions are toxic to living organisms and higher amounts of these metals may inhibit self-purification of rivers. The metallic contaminants destroy bacteria and other organisms which act on water to purify it. In addition, aquatic plants and animals are also killed. If the industrial waste is discharged into sewers, metals are precipitated and settle down with the sewage sludge. Coetamination of rivers with toxic metals prevent the further use of the water for industrial purposes and drinking purposes. Arsenic and lead particularly make the water dangerous to drink. These toxic materials are reported to cause chromosome damage and thus interfere with the process of heredity. In human beings, a concentration of 80 micrograms of arsenic per 100 grams of blood causes poisoning in adults. It is also reported that lead above the level of 40 micrograms per 100 grams of blood causes brain damage to children. Small increases in mercury levels are reported to cause damage to the growth of aquatic algae. These metals are also toxic to fish. It is suggested that heavy metal ions precipitate the mucous secretions of the gills. These precipitates occupy the interlamellar spaces and the movement of the gill filaments becomes arrested and respiration is prevented. Copper in about 2 parts per hundred million parts of water is fatal to sticklebacks. The lethal concentrations of nickel, lead and zinc is about 1 ppm.

Pollution of the sea by metallic contaminants occurs through the dumping or discharge of industrial and domestic effluents or from polluted rivers and to some extent from air. Metals are considered to be the indestructible poisons and their dispersion into seas over long periods may be highly dangerous since it may affect the production of atmospheric oxygen as well as marine life.

Oils : Replacement of coal by oil fuel has increased the problem of pollution. The presence of oil in a water course is undesirable since it creates aesthetic problems. It has a tendency to spread over the surface of water and the diffusion of oxygen into water is inhibited and reaeration of water is affected. The absorption of oxygen from air into water depends on the thickness of the film formed by oil. When the thickness of the film increases even above 0.001 mm a marked effect on the absorption is observed. Oil is reported to coat the gills of fish and thus affect respiration of fish. Oil pollution of sea causes some other problems. Oil is pushed to the shore by the water currents and winds. Thus beaches are spoiled and bathing becomes impossible in such places. A report from Britain indicates that sea-birds around Britain are badly affected by oil pollution.

In addition to the above 'water-insoluble' oils, 'soluble oils' also cause serious pollution. The soluble oils are classified as 'cutting oils' and 'degreasing oils'. Cutting oils are homogenous mixtures of oil emulsified in water with the aid of an emulsifying agent. A little amount of alkali and cresol are also added. These cutting oils are used in engineering factories as coolants and lubricants. Degreasing oils are mixtures of organic solvents and emulsifiers. They have a higher pH value by which degreasing is effected. All these soluble oils form milky emulsions with water and the formed emulsions are very stable and not destroyable by easy means. These oils go into drains and ditches, where it can eventually clog up sewage works and cause river pollution.

River pollution by oil occurs through the discharge of industrial wastes from metallurgical industries, engineering industries and garages. Tankers, barges and boats also introduce oils to rivers and canals.

The sources of oil pollution of sea are considered to be the following :

1. Discharge of oily wastes such as tank washings etc.
2. Maritime accidents which result in the release of oil.
3. Spillages while transferring fuel or cargo from ship to ship, or ship to shore.
4. Accidental spillages occurring due to the incorrect operation of valves, etc., on ship board or at oil terminals.

These oils are mainly constituted with hydrocarbons and the presence of oil even in trace amounts is detectable by the characteristic fluorescence. However, it must be noted that oil pollution is only occasional or intermittent and not continuous as other types of pollution are.

Protein and carbohydrates

Faeces and household wastes in sewage are the principal contributors of proteins and carbohydrates to a water course. Carbohydrates are compounds of carbon, hydrogen and oxygen and are distributed in plant and animal kingdom widely. Glucose, sucrose, starch, dextrin, cellulose, glycogen and alginic acid are some of the carbohydrates. Sugar factories, glucose factories, sweet manufacturing industries, dairies, breweries, wood processing industries, food processing industries, and textile industries contribute sugars and starch. Proteins are a group of organic nitrogenous compounds of high molecular weight, distributed widely in plant life and animal kingdom. The main component of proteins are amino acids. Proteins vary in their nature according to the number of amino acids present, their order in the chain and the geometrical shape of the molecule. Apart from carbon, hydrogen oxygen and nitrogen, proteins also contain sulfur and phosphorus. Egg albumin, gelatine, casein, keratin, glutenin are some of the examples of proteins. They undergo putrefaction by bacterial action to release primarily sulfur and phosphorus compounds. The released sulfur compounds on further action by bacteria produce sulfuretted gases such as hydrogen sulfide which in turn produces a putrid smell. Phosphorus compounds on the other hand causes musty smell.

Plastics and rubbers

Plastics are the resins of phenol and formaldehyde. When plastics are burnt, polychlorinated biphenyls (PCB) seem to escape into the environment.

Rubber is discharged from rubber manufacturing and processing industries. Rubber is a polymerised product obtained from isoprene, a hydrocarbon.

Dissolved solids

Chlorides, sulfates, nitrates, bicarbonates and phosphates of sodium, potassium, calcium, magnesium, iron and manganese, and some of the fluorides are soluble in water. Water softening plants and drainage from salt works contribute many of these salts to rivers and streams. Fluorides and nitrates are considered to be toxic to man above a certain level. Fluoride is present in almost all water supplies. Waste discharge adds to the concentration of fluoride. If the concentration of fluorides in drinking water is less than 0.5 ppm dental caries may appear. If the concentration exceeds about 1.5 ppm mottling of teeth occurs. Still higher amounts cause skeletal fluorosis, i.e., bone disorders. The control and the action of knees and bone joints are affected due to skeletal fluorosis. Not only human beings but cattle and other livestocks are also attacked by dental and skeletal fluorosis. Fluorides also attack plants. To know the complete effects of fluoride on human health, plants and animals the readers are directed to refer Chapter VIII.

Nitrate generally occurs in trace quantities in surface waters. The nitrate content of ground waters are appereciable. Nitrate is mostly derived from nitrogenous organic matter of animal origin. When the water is used for potable purposes the amount of nitrate should not exceed 20 ppm. A range of concentration between 20-40 ppm is reported to cause 'methemoglobinemia' in infants. This disease is characterised by blood changes and cyanosis. Nitrate is reduced to nitrite which causes a partial conversion of haemoglobin to methaemoglobin which affects the transport of oxygen and a greyish-blue or brownish-blue cyanosis occurs in infants. River pollution by nitrate occurs through the discharge of effluents and waste water from cooling systems.

When waters containing excessive salts are discharged into rivers, the river course becomes brackish which affect fish life and certain vegetation. Many of the fresh water fish varieties die in salt water and this is entirely due to osmotic changes. Not only these soluble salts affect biological organisms but they also cause severe effects to pipelines, pumps and other metallic or concrete structures. Sulfates are converted either into sulfuric acid which aids corrosion or into sulfides which produces odor nuisances. The conversion of sulfates to sulfides is brought about by sulfate reducing bacteria and sulfur bacteria.

Certain soluble salts of iron and aluminium react with the natural bicarbonate alkalinity to form insoluble hydroxides. When the river or stream is depleted of dissolved oxygen due to sewage or other contaminants, the water may turn black due to the formation of ferrous sulfide. Iron can react with phenols to form varied coloured compounds and make the streams coloured.

Synthetic detergents

Synthetic detergents have been developed only recently and the use of these compounds increased enormously. Synthetic detergents are used as household cleaning materials and industrial cleaning agents. A point to be noted is that natural detergents exhibit only a little toxicity. It is considered that the toxicity of synthetic detergents may also be due to its non-biodegradability. The intoxicity is completely attributed to the alkyl benzene sulfonate which is the active ingredient.

Synthetic detergents have only a small proportion of surface active materials (ranging from 15-35 per cent) and the remaining percentage is constituted with substances known as fillers. These fillers include phosfatic compounds such as sodium tripolyphosfate, sodium hexametaphosfate and other phosfates of sodium, sodium carbonate, sodium silicate, borax, and sodium carboxymethyl cellulose which improve the detergent action. In addition to the toxicity caused by the surface active materials, a concentration of soluble salts in water also occurs when these wastes are discharged.

Synthetic detergents are classified into three groups : (i) Anionic detergents, (ii) cationic detergents and (iii) non-ionic detergents.

The most widely used type of detergents is anionic (about 95 per cent). The remaining usage is attributed to noni-onic detergents. The cationic detergents are rarely used owing to their higher cost. The increased use of syndets replaced other surface active agents such as soap etc., and the possibility of these materials to occur in sewage and industrial effluents is also increased. The active ingredients are not easily degradable which produce nuisances at sewage works by causing foam and froth. About 50 per cent of these substances are reported to be present even in the final effluent also. As these compounds are able to produce foams even in very low concentrations aeration is not possible, since aeration tends to increase the amount of foam once again. Hence, the rate of re-aeration of a river water is reduced as well as the efficiency of sewage purification. Moreover, the aquatic flora and fauna are destroyed due to the toxicity of these syndets. Syndets also produce some tastes in water supplies. Laboratory experiments proved that water plants are adversely affected by syndets.

Other inorganic and organic pollutants

Apart from the substances discussed earlier, some of the important substances have also to be discussed separately. They are mercury and mercuric compounds, cadmium, polychlorinated biphenyls, phenols, hydrocarbons, polynuclear aromatic hydrocarbons and aldehydes.

Mercury and mercuric compounds

In very recent years, a lot of attention has been given to the problems of mercury poisoning. Natural waters contain only a few parts per billion of mercury. Mercury enters the biosphere as a waste product from a number of industrial activities. A major source is the production of chlorine where mercury is used as an electrode in the electrolysis of brine. Paper and pulp industries, oil refining industries, plastic industries and battery manufacturing industries also contribute to mercury pollution. Mercuric compounds are also used as fungicide to prevent seeds from rotting and for the protection of various plants. But the use of mercuric compounds as fungicide and insecticide are declining due to the acute poisoning nature. Metallic mercury in the liquid form is not toxic. But the vapours of mercury affects the central nervous system. The most widely used organic compound of mercury is methyl mercury. This is most injurious and poses the greatest environmental threat. However, it is to be remembered that mercury discharged from industrial process is mostly in inorganic form. But, anaerobic bacteria in the mud at the bottom of a lake converts inorganic mercury into methyl mercury. Therefore, the mercurial wastes that have accumulated in muddy lake bottoms cannot be regarded as sludge; actually they are the potential sources for biochemical conversion into forms of mercury that can concentrate in the food chain and thus become poisonous to man. Hence, the large quantity of inorganic mercury already in the environment will be a significant threat far into the future. An important episode, which occurred during the year 1960 in Japan has to be mentioned here. It is reported that 116 people had been irreversibly poisoned, and consequently, brain cell damage occurred. In the subsequent years there were so many deaths, as a result of mercury pollution due to the discharge of effluents from a local plastic industry.

Cadmium and Cadmium Compounds

Cadmium ranks next to mercury in its toxicity. The principal contributor of cadmium is electroplating industry. Cadmium tends to concentrate in the liver, kidneys, and thyroid of human beings and animals. Once it enters the body, it is likely to remain. Consumption of cadmium salts causes cramps, nausea, vomiting and diarrhoea.

Polychlorinated biphenyls :

These are used commercially in plasticizers, dielectrics, and lubricants and are being concentrated in the food chains of marine ecosystems. PCBs are similar to DDT and can cause similar physiological reactions. They can be released into the environment when certain plastics are burned. Like DDT, PCBs can cause thinning of the shells of birds' eggs.

Phenols and phenolic compounds :

Phenols are common constituents of many important trade wastes. These compounds will produce characteristic tastes in water when present even in very low concentrations. Concentrated solutions of phenol will result in severe pain, renal irritation, shock and possibly death.

Polynuclear aromatic hydrocarbons

Many polynuclear aromatic hydrocarbons are found in water and also in other environmental media. They are less soluble in water but the solubility is increased by the presence of anionic detergents. The stability of polynuclear aromatic hydrocarbons is affected by light and oxygen. The health significance of traces of carcinogenic polynuclear aromatic hydrocarbons in fresh waters is not yet known.

Other hydrocarbons

These compounds are said to impart an odour similar to benzene. However, the odour is dependent on the volume of gas, the volume of water and the period of contact.

Aldehydes

The important compounds of this type are acetaldehyde, benzaldehyde, formaldehyde, furfural and vanillin. These compounds may cause odours in water and are toxic to fish. The growth of algae is also reported to be inhibited by vanillin.

Suspended matter

Insoluble matter in suspension is one of the commonest forms of pollution. Suspended matter is present in sewage and in most of the industrial waste waters. Suspended matter may be inorganic or organic or both inorganic and organic in nature. Wastes from stone quarrying works, sand-washing, China-clay works and paper and pulp industries contain primarily inorganic suspended solids. Sewage effluents and many coal washery effluents contain suspended solids which are organic in nature. Supended matter, though not causing any harm is objectionable because it interferes with the self-purification of streams by reducing the photosynthetic activity of water plants and by smothering benthic organisms. Moreover, abrasive materials present in the suspended matter can choke the gills of fish and thereby cause damage to fisheries. Deposition of suspended matter on stream bed destroys plant and animal life and thus the food supplies for fish are diminished. A report by Patrick* indicates that the eggs of fish can become buried by suspended solids. The coal washery waste waters which are black and opaque, discolour a stream and render it unfit for most uses. Suspended matters containing organic material, will undergo putrefaction during warm weather. As a result, solids buoyed by gas may rise to the surface, leading to the formation of floating masses of evil-smelling sludge.

Heated effluents : Refer Chapter VI, "Thermal Pollution".

Radio-active substances : The readers are directed to refer Chapter V, "Radio-active Pollution".

Biological pollutants

Biological pollutants may conveniently be classified into two groups as primary pollutants and corollary pollutants. Primary pollutants comprise biota that are added to water directly as a result of man's activities (e.g.) pathogenic bacteria or viruses from sewage. Corollary pollutants are the indigenous living materials that interferes with the beneficial uses of water (e.g.) weeds in irrigation ditches. Corollary pollutants although not added directly to the water course by man, are attributable to human endeavor. While primary pollutants have very short life, corollary pollutants have a longer life. The organisms that constitute primary and corollary pollutants are numerous. A detailed study of these is beyond the scope of this book. However, the nature and effects of some of the important primary pollutants such as bacteria, viruses, and corollary pollutants such as algae, are discussed in the following pages.

Bacteria : Bacteria are widely distributed in nature. Bacteria are minute living unicellular microorganisms. They may occur singularly or in aggregates. They are unable to synthesize their food and are dependent upon dead or living organic matter. Bacteria have an extraordinarily broad range of biochemical activity and because of this capacity most bacteria are beneficial to man. Bacteria perform an important role in the life processes on earth by concentrating the elements essential to life itself for use by other species and other forms. They also make available essential nutritional factors that have been stored until death in the bodies of animals and plants. Because of this nature, bacteria are considered as the work-horses of biological sewage treatment plants and of the natural purification phenomena of rivers, lakes and streams.

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* Patrick, R (Miss), "Aquatic organisms as an aid to solving waste disposal problems"—Sewage Industries Wastes, 25, 1943 pp 210-14.

Bacteria are categorized as saprophytic and pathogenic. The saprophytic bacteria are harmless and beneficial while the pathogenic bacteria are harmful. It is considered that it is enough to discuss only pathogenic bacteria while dealing with pollution problems. Even though the life time of the pathogenic bacteria is short, the effects made within that time are great. Several diseases are transmitted to man by these pathogens through contaminated water supplies. Among them, cholera, dysentery, typhoid fever, gastroenteritis are the most common and severe. Other diseases such as leptospirosis, brucellosis, and tularenia are less common. Some diseases such as brucellosis, tularenia and tuberculosis are common to man and certain animals and they may therefore be transmitted in water, polluted by animal discharges.

Among the pathogenic bacteria, Salmonella, Shigella, Vibrio cholera, Leptospira, Mycobacterium tuberculosis and Pasteurella tularensis are the most important.

Viruses : The problems associated with viruses in waters are of increasing concern. Viruses are infectious agents of both plant and animal cells. They are ultramicroscopic, obligate intra-cellular parasites. Their presence is manifested by the destruction or impairment of the host cells. They are devoid of any intrinsic metabolism and they have to depend only on the host cell for development and replication.

A report by Derby *et al.* (1960) indicates that nearly seventy-six viruses are pathogenic to man. Among them, Enteroviruses Adenoviruses, Polioviruses, Infectious Hepatitis viruses, and Coxsackie viruses are the most common viruses present in polluted waters and sewage. One of the most important and dreaded of virus diseases is poliomyelitis. It may cause paralysis of one or more parts of the body by the destruction of certain nerve cells controlling the muscles. The disease occurs all over the world.

It is to be remembered that the viruses are not attacked by combined chlorine* and they are affected only by free chlorine.** Hence the chlorine dosage applied should be more than that of vegettative bacreria.

Algae : The algae constitute a group of life forms that may be unicellular or multicellular, motile or non-motile. All of them have photosynthetic pigments. Since algae occur naturally in surface water, they are classified as corollary pollutants. They play a dual role in water. In some aspects algae are beneficial and in other aspects it is objectionable. By means of photosynthesis, they remove carbon dioxide and add oxygen to water and thus are significant in natural purfication procesess of water. They also form food for certain types of aquatic fauna. However, they are reported to be the producers of organic materials and the objection arises there.

Algae are responsible for communicating peculiar tastes and odours to many of the water supplies (Refer : Palmer, C. M., "Algae in water Supplies", U.S. Public Health Service, Publication No. 1657, 1959). A report by Fox (1953) indicates that, very low concentrations of blue green algae can cause a grassy or moldy odour. The green algae produce a naisturtium like odour at high concentration. Apart from odour and taste, algae impart colour and turbidity to water. Algae are considered to be indirectly responsible for gastroenteritis. The accumulation of dead plankton in sand filters offers a substrata for the growth of such bacteria as Pseudomonas some species of which cause gastroenteric disturbances. Apart from this some of the algae are deadly poisonous. A report by Wheler *et. al.* (1942) indicates that algal poisons usually act on the central nervous system and skin. Further, algal poison is considered to be one of the most virulent poisons and is reported to be capable of producing cirrhosis of the liver. It has also the capacity of reducing resistant power against disease of many human beings. Algae may also interfere with the water treatment processes such as sand filtration and disinfection. Filaments of some of the algae are capable of clogging filters. Algae are reported to reduce the useful capacity of reservoirs by concentrating at certain depths, in the water or along the shallow margins or bottom.

Algae can cause heavy mortality in fish through poisoning.

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* Combined chlorine—in the form of chloramines and other chloro derivatives.

** Free chlorine—in the form of hypochlorous acid or hypochlorite ion or both.

Algae can deplete oxygen or supersaturate the stream with oxygen and subsequently an imbalance in oxygen content will be set up because of which fishes may be killed. Dead algae can clog the gills of fish and thereby death may occur (Refer, J. R. Erichsen Jones, "Fish and River Pollution" Butterworths, 1964). Further, the dead algae form a mat on the surfaces and act as barriers so that penetration of oxygen is prevented.

Excessive growths of algae destroy the recreational and aesthetic values of lakes. They are concentrated in a large mass on the shore by wave action. If they are not removed immediately, they cause unpleasant septic odour which are produced by decomposition.

Other nuisance organisms

Apart from bacteria, viruses, and algae there are numerous organisms which are a nuisance to man. Among them, parasitics are of considerable importance. Eggs of nematode worms and tapeworms are common in crude sewage. When such sewages are discharged into water courses without treatment, contamination of water occurs with resultant danger to man and animals. Of the parasites that may be ingested, Entamoeba histolytica is the casual agent which causes both internal amoebiasis such as amoebic dysentery and extra-intestinal forms of the disease. The guinea worm, which causes dracontiasis, is transmitted through open village wells and ponds infested with the copepod intermediate host. Intestinal helminths, such as Ascaris lumbricoides and Trichuristrichiura are also reported to be water-borne. Heavy chlorination is needed to destroy the eggs and cysts of these parasites.

In spite of discussions regarding important pollutants and their effects, it is necessary to discuss separately some of the physical and physiological effects caused by many of the pollutants. They are, colour, turbidity, foam, tates and odour. Though these effects are disucssed then and there, a detailed study is necessary and is as follows :

Colour : Most of the trade wastes discharged into river have pronounced colours which they may impart to the water. The colour in these wastes is mainly due to organic dyes. However, highly coloured substances of inorganic origin also contribute to colour, e.g., chromium and iron compounds. A fact to be remembered is that colour in itself is not necessarily harmful. However, aesthetic considerations make coloured water unsuitable for any purpose. It is reported that the organic dyes when present even in micro-quatities can impart colour. For example, a concentration of 0.02 ppm of magenta in water imparts a distinct red colour to the water. Interaction between two effluents or between a trade effluent and substances that are naturally present in water, can sometimes cause an intense colouration. Redlich* (1953) states that tannery wastes when discharged into iron containing streams may cause deep green or inky-blue colourations due to the interaction of tannins with iron.

Turbidity : The turbidity which is caused by the presence of colloidal matter or very fine suspended matter is one of the important physical characteristics of sewage and industrial effluents. Colloidal particles do not settle and fine suspended matter settles with difficulty. Hence, there is no sharp line of demarcation between colloidal particles and suspensions. Generally, the more the turbidity, the stronger is the sewage or effluent and the effects are worse. Therefore, the degree of turbidity of a water course may be taken as a measure of the intensity of the pollution. The turbidity measurements are helpful in the evaluation of the effects of pollution by waste waters. They are also used to follow the course of self-purification of rivers or streams. However, the absence of turbidity does not mean that the water is unpolluted, since clear waters may be heavily contaminated with acids or toxic materials which do not cause turbidity. Turbid waters are not only unsuitable for industrial purposes but also for domestic purposes since the iron and manganese present in it may cause stains on clothes, baths, sinks, wash-basins etc.

Foam : Many substances such as soaps and detergents are known to cause foam in water. Foam consists of a suspension of air bubbles in water medium. As discussed earlier, the increasing use of synthetic detergents is the prime reason for foams on rivers and at sewage treatment works. In addition to syndets, a small fraction to foam is contributed by the untreated alkaline organic effluents from paper and pulp industries. Foam is produced by the lowering of surface tension of water and sewage. According to

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* Redlich, H.H., "Problem of Tannery Waste Disposal", Jour. Leather Chem. Ass. 48, 1953, pp 422-36

Truesdale *(1958), the tendency to foam is great in relatively clean waters. It decreases as the pollution increases and as the sewage purification begins the degree of foaming increases. Thus all the sewage treatment processes from the beginning to end are affected. Even the final effluent from sewage treatment plant is reported to contain a considerable amount of syndet. However, many methods have been proposed for the control of foam.

Taste : Industrial effluents containing chemical substances such as iron, free chlorine, and phenols impart characteristic and unpleasant tastes to water. For example, 0.1 ppm of ferrous iron can produce an inky taste. According to Southgate (1948), phenol produces a taste when present in water to the extent of 7 ppm. When a water containing phenol is chlorinated, chlorophenols are formed which have a characteristic taste and odour. Manganese, synthetic detergents, oils, petroleum products, and hydrocarbons are the other substances reported to produce tastes in water. The decomposition of organic matter and algae, fungi and filamentous bacteria imparts peculiar tastes. Unpleasant earthy or musty tastes and odours are produced by aquatic actinomycetes. The taste producing substances can be removed by conventional water purification processes such as chemical precipitation, chlorination and treatment with activated carbon.

Odour : Odour in a water course is one of its most important characteristics. It is caused both by chemical agents such as free chlorine, phenols, hydrogen sulfide and ammonia and by biological agents such as algae and micro organisms. The commonest form of objectionable odour in streams and other water bodies is attributed to the presence of small amounts of sulfides. The extent of odour depends upon the pH of water. The lower the pH, higher will be the amount of hydrogen sulfide produced and odour nuisances will be great. The presence of inorganic and organic compounds of nitrogen, sulfur and phosphorus and the putrefaction of proteins and other organic materials present in sewage and in trade wastes are the causes for odour in polluted rivers. Many of the industrial effluents containing organic substances, (e.g., phenols, alcohols, esters, aldehydes,

* Truesdale, G.A., "Foaming of liquids containing synthetic detergents", Water and Waste Treatment Journal 7, 1958, pp 108-111.

ketones and sulfur comopunds) possess characteristic odours and are imparted to the receiving water.

Microorganisms of certain type are reported to be responsible for odours in water supplies. For example, the protozoa Dinobryon imparts a fishy odour to water. The algae Oscillatoria and Rivularia produce a mouldy odour and the algae Anabaena, a strong grassy odour. It is suggested by Fair and Whipple (1927) that liberation of traces of essential oils is the reason for the production of odour.

The Royal Commission on Sewage Disposal*, London, classified the smells from polluted rivers as follows :

1. Putrid smell (mainly due to hydrogen sulfide)
2. Fishy smell (probably due to organic amines)
3. Wormy smell (may be due to phosphorus compounds)
4. Earthy smell (due to humus)

Odours in drinking-water can be eliminated by the use of activated carbon. In addition to the removal of odour it also eliminates tastes. Aeration is another method of removal of odour. Chlorine, chlorine dioxide and ozone may also be used in the removal process. Chlorination is reported to be a useful method in controlling odours of some of the industrial effluents.

We have discussed so far the sources, nature and effects of water pollution in general. The treatment procedures, prevention and control of water pollution have not yet been discussed. The treatment procedures, however, vary according to the sources of pollutants. Hence, it is necessary to discuss the pollution problem further under the following heads to understand the subject more clearly. They are :

1. Water Pollution : Municipal
2. Water Pollution : Industrial
3. Water Pollution : Agricultural

A separate section "Measurement of Water Quality" has also been included lastly in order to enable the readers to know some of the analytical aspects and standards of water quality. All these sections are discussed only briefly. If more information is needed, the readers are directed to refer the publications given in the reference column.

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* Royal Commission on Sewage Disposal, 8th Report, Vol. II, Appendix. Report on results of stream observations during 1909-12. Part 2, Sect. 4, page 110 and 6943, Her Majesty's Stationary Office, London, 1918.

Water pollution : municipal

Both great cities and smaller ones need a water supply that is adequate quantitatively and qualitatively. Whenever there is a water supply, then there should be a means of disposal of their water wastes also. Since, many new towns have arisen and the existing towns have grown, sewer system and sewage treatment plants are necessary. This section describes Municipal sewage, its composition and effects and sewage treatment methods.

Sewage is obtained from the disposal of wastes from lavatories, bathrooms, kitchens, laundries, laboratories, etc. Sewage also results from the disposal of waste in factories and trade premises and also from the use of water in dwellings, hospitals and schools. Sewage as commonly known is a cloudy dilute aqueous solution containing mineral and organic matter. They include large aad small particles of solid matter floating, and in suspension and colloidal and pseudo-colloidal dispersions. Domestic sewage primarily is composed of spent water which comprise urine, faeces, soapy wastes, food materials, paper and dirty water. Apart from these inert materials, sewage also contains living matters, especially bacteria, viruses and protozoa. Sewage may vary considerably in composition and strength from country to country and from town to town due to the marked differences in the habits of the people, the nature of the diet, the water consumption and the composition of the industrial wastes present. The composition, character and appearance of sewage is profoundly modified by the presence of industrial effluents. It is to be noted that though it appears to be high, the solid content of sewage matter is actually much less. The total dry solid matter (organic and inorganic) constitutes only about 0.1 per cent of the total. The remaining 99.9 per cent portion is completely water. It has to be mentioned that the ratio of carbon to nitrogen in settled domestic sewage is always lesser than that of industrial wastes since trade wastes contribute much organic matter. The nitrogen in sewage is usually present in two forms. Ammoniacal nitrogen which is also referred as free or saline ammonia constitutes about 50 to 75 per cent of the total nitrogen. The organically bound nitrogen is mainly derived from proteinaceous matters. The domestic sewage contains large amounts of urine. Urine contains about 2.5 per cent urea, 1 per cent sodium chloride and other complicated organic substances. Sodium chloride is also derived from many of the industrial wastes. Other inorganic coustituents such as sulfates, and bicarbonates of calcium and sodium are present in considerable amounts in sewage.

Special mention has to be made of synthetic detergents. These are of recent origin. Present-day sewage contains appreciable quantities of synthetic detergents. In addition to the surface active agents they also contribute phosphates of sodium and other 'builders.' Faeces and household wastes contain primarily fats, soaps, proteins and carbohydrates. They are present in sewage as suspended matter as well as matter in colloidal and true solution. A report from Water Pollution Research Laboratory (London) indicates that even trace amounts of metals such as copper, chromium, zinc, manganese, lead and nickel are present in domestic sewage.

Because of its varied content of easily decomposable matters, sewage is an excellent medium for the growth of bacteria. Though bacteria is abundant every where, the quantity of bacteria present in sewage is very high. In addition to the saprophytic* bacteria which are harmless, pathogenic** bacteria are also found in sewage. Among them, the most important are 'Vibrio cholerae' (causes cholera), 'Salmonella typhi' (causes typhoid fever), and Shigella dysenteriae (causes bacillary dysentery). It is reported that many of the sewages contain these pathogenic bacteria even after treatment and the chances of the pathogens mingling with river water is quite high. Hence for complete safety, chlorination is necessary. However, it should be remembered that pathogenic bacteria have only a short life in water and are less resistant. In addition to bacteria, the ova and larvae of many worms are parasitic to man and may be passed out in the faeces thereby contaminating the receiving water.

Harmful effects of sewage

The oxidisable and fermentable matters present in sewage cause a depletion of dissolved oxygen in the receiving water. Thus the aquatic life are completely affected. Moreover, deficiency of oxygen leads to the production of objectionable odours. The presence of large quantities of suspended matter creates serious problems. Suspended matter is deposited on the river bed or behind weirs as sludge. When the suspended matter is highly organic in nature, putrefaction occurs. As a result the solid wastes are buoyed up by gas which results in offensive odorous matter floating on the water surface. Moreover, suspended matter has a tendency to blanket the stream thereby interfering with the spawning of fish and resulting in a reduction in the number of other animal life which form food for fish. Moreover, pathogenic micro-organisms are introduced into the water course which cause severe diseases in man and animals.

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* **Saprophytic bacteria—bacteria which only feed dead organic matter.**
** **Pathogenic bacteria—bacteria which cause disease in man and animals.**

Treatment of Sewage

Treatment of sewage aims in the removal of BOD*, phosphorus, nitrogen, solids and bacteria. Treatment processes are generally divided into three groups :

(i) Primary treatment : Usually mechanical process
(ii) Secondary treatment : Biological process
(iii) Tertiary treatment : These are the advanced biological, chemical and physical processes.

Primary Treatment

Primary treatment includes, screening, grinding, flocculation and sedimentation. Screening in the process by which the larger suspended and floating materials such as paper, rags, wooden pieces, wires are removed. Screening system is composed of two units : The first one known as coarse screen consists of metal bars or heavy wires spaced 25 to 50 mm apart while the second unit finer screens may range down to 0.8 mm openings. The materials that are removed by screening are usually incinerated. The grinders consisting of rotating screens with cutting teeth are used to chop the solid materials to size smaller than 6 mm. Flocculation is actually an agitation process which makes the smaller suspended particles to form flocs. The formed flocs will settle out rapidly. The next step is sedimentation, the process by which the suspended solids are removed by gravitational settling. A report by American Chemical Society indicates that primary treatment reduces about 60 per cent,

* BOD—Biochemical Oxygen Demand.

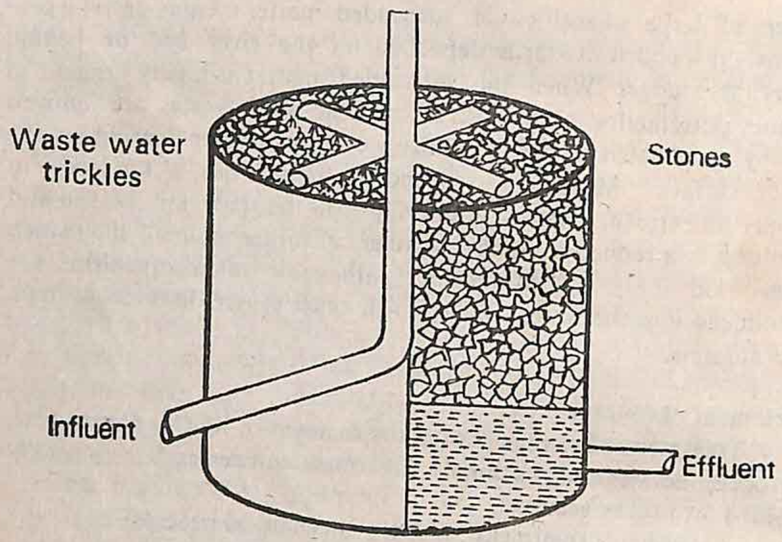
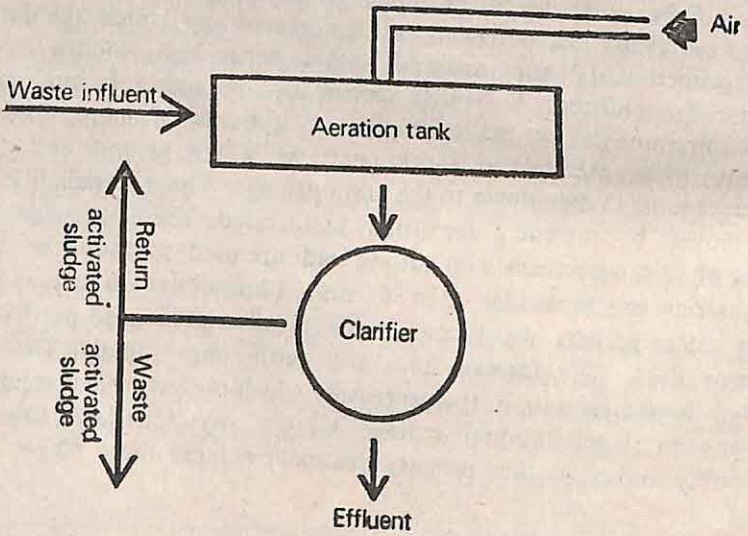


Fig. 8 Cut-away view of Trickling Filter

35 per cent, 30 per cent, 20 per cent and 10 per cent of the total suspended solids, BOD, COD*. total nitrogen and total phosphorus respectively.



Tig. 9 Activated Sludge System

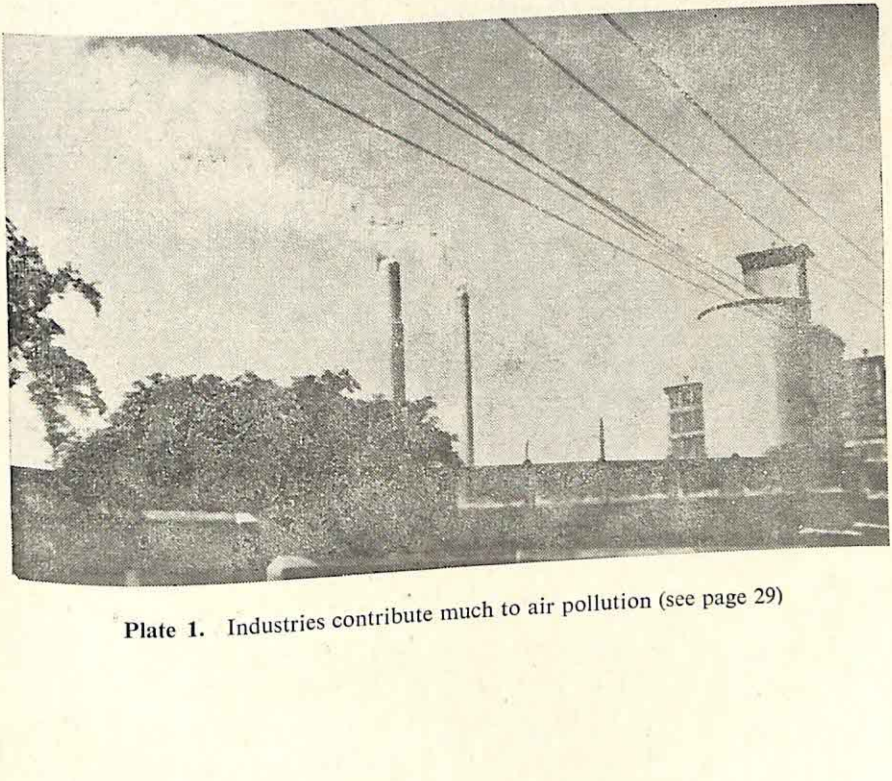


Plate 1. Industries contribute much to air pollution (see page 29)

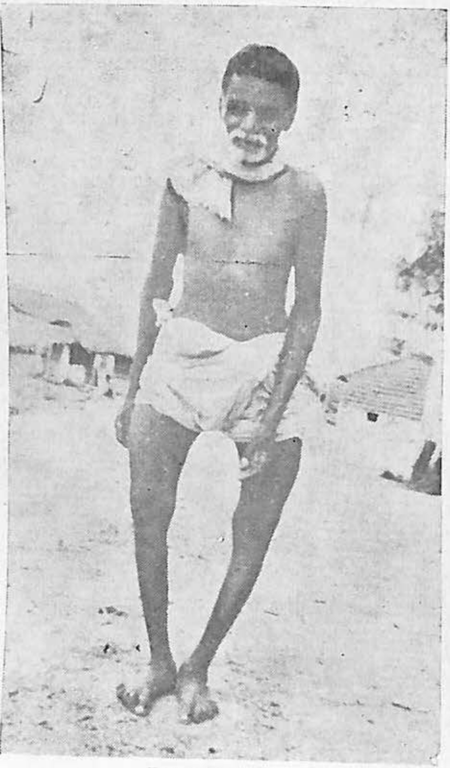
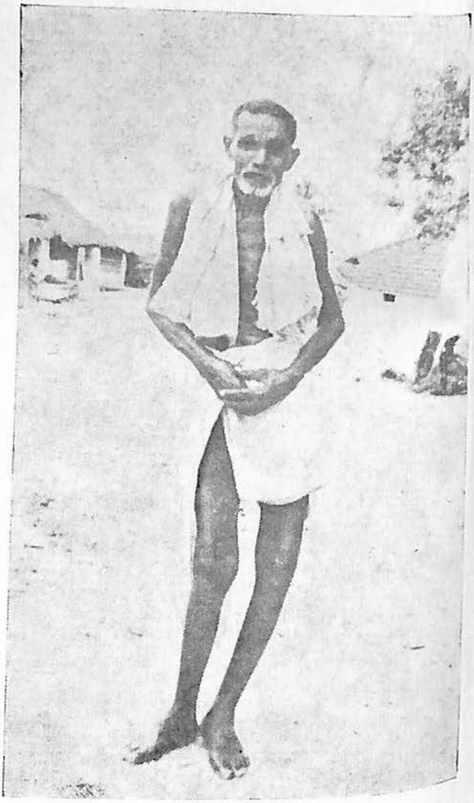


Plate 2 & 3.
Excess fluoride in drinking water causes skeletal fluorosis and bone disorders (see page 84)



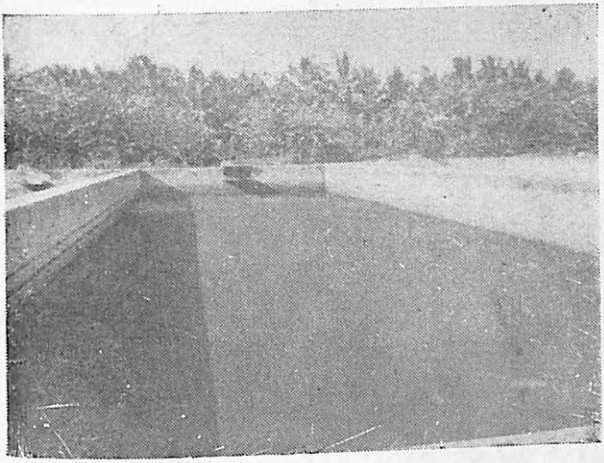


Plate 4. A typical sludge drying bed (see page 61)

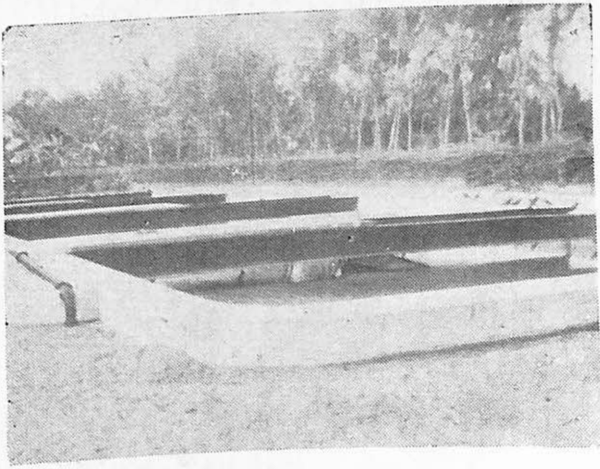


Plate 5. A view of sedimentation tanks (see page 59)

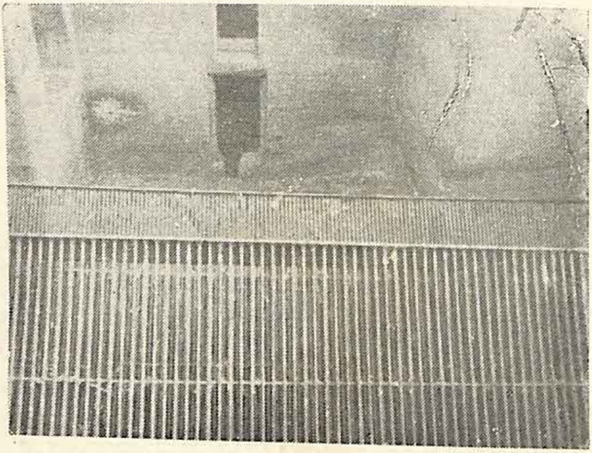


Plate 6. Screens (see page 59)

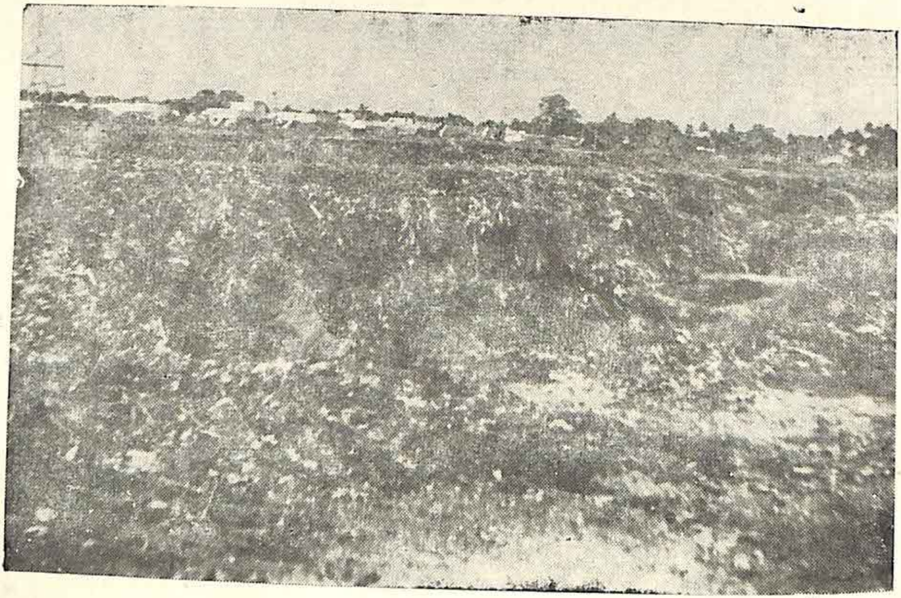


Plate 7. Dumping of solid waste causes numerous public health problems (see page 96)

Secondary treatment

Secondary treatment involves the use of biological methods, particularly trickling filters and activated sludge processes. Purification by treatment on trickling filters is a biological process depending primarily on absorption and absorption of both soluble and suspended matter from the waste water into and onto zoogloeal slimes. These slimes develop and proliferate on the surfaces of the filtering medium over which the water trickles. When the waste water flows through the beds, decomposition of the materials occurs and both the soluble substances and sludge-forming solids are synthesized. These decomposition and oxidation processes are carried out by bacteria, fungi and protozoa, together with other living organisms which feed upon them preventing unrestrained accumulation and clogging. When wastes are fed onto such filter beds, they trickle or percolate over the stones (or other filling materials of the beds), a covering of zoogloeal slime develops gradually. When the slime layers become very thick, they slough off and can be removed.

In the activated sludge processes, which is somewhat more popular than trickling filters, biologically active growth are continuously circulated through organic waste in the presence of oxygen. Aeration activates the sludge particles so as to develop an active culture of aerobic organisms. Thus a contact treatment is possible by the accumulation and circulation of sufficiently large quantities of activated sludge. Actually, the fundamental principle is the same as that in the self-purification of natural waters and the difference is that the waste water is subjected to vigorous aeration by artificial means together with turbulence, whereby the activated flocs are kept in suspension and the mixture of waste and sludge are thoroughly mixed in the presence of sufficient dissolved oxygen at all times. The basic phenomenon of activated sludge process given by Buswell and Long is as follows :

"The purification is accomplished by digestion and assimilation by organisms of the organic matter in the sewage and its resynthesis into the living material of the flocs. This process changes organic matter from colloidal and dissolved states of dispersion to a state in which it will settle out."

The basic difference between activated sludge process and trickling filters is that there is no medium to support the active zoogloeal slime in the activated sludge process.

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* COD—Chemical Oxygen Demand.

Handling and disposing of the sludge from secondary treatment plants are the other important problems. Several methods are used in handling sludge. One of the best methods is concentration with subsequent digestion of sludge. Another method constitutes drying of sludge on sand beds after de-watering sludge. The dried sludge is usually incinerated and sometimes it is subjected to compositing. It is also used in sanitary land fills along with other refuse.

Secondary treatment combined with primary treatment offers a reduction of about 90 per cent BOD, 80 per cent COD, 50 per cent total nitrogen and 30 per cent total phosphorus. The reduction in suspended matter is estimated to be about 90 per cent. Primary and secondary treatments are largely developed to reduce BOD and suspended solids and it is to be noted that temperature is one of the important factor which strongly affects the efficiencies of the treatments. It has to be mentioned that secondary treatment is often inadequate during cold weather.

Tertiary treatment

Tertiary treatment not only aims at further purification of waste water but also in the recycling of waste water. The increasing costs of water supplies force us to recycle the waste water and indeed in many of the scarce areas waste water is recycled and utilized for a number of purposes. It is not necessary to introduce tertiary treatment only after primary and secondary treatments and it can be applied at any stage of the total treatment. The prime purpose is the more efficient removal of pollutant than primary and secondary treatments.

A number of methods are used in advanced waste treatment. They are :

(*i*) *Chemical coagulation and filtration* : Though this technique is used in water purification, it can also be used as a waste water treatment method. The coagulants react with suspended matter to form flocs which settle out rapidly. The important chemical coagulants are alum (aluminium sulfate), copperas (ferrous sulfate, $FeSO_4 . 7H_2O$), and ferric sulfate. After coagulation, filtration is achieved through sand filters or other synthetic filter media.

(*ii*) *Adsorption* : This process is used to remove odours and tastes. Activated carbon* is the universally employed adsorbing material.

(*iii*) *Chemical oxidation :* Waste water is oxidised by using ozone or hydrogen peroxide so as to get purer water.

(*iv*) *Desalination :* Desalination is the process by which the dissolved substances are removed. A wide variety of methods are employed for desalination. Among them, ion exchange, electrodialysis and reverse osmosis are the most important techniques.

(*v*) *Oxidation ponds :* New biological methods are introduced now-a-days for waste water treatment. The oxidation pond is the commonest of all of them. Oxidation pond is nothing but a shallow pond where waste water is permitted to be purified by the action of algae and aerobic bacteria. Organic matters are decomposed by bacteria and are consumed by algae. These algae release oxygen during photosynthesis and thus BOD of the waste water is greatly reduced.

Although tertiary treatments seem to be useful, the costs are higher than those of primary and secondary treatments.

Water pollution : industrial

Industrial activities generate a wide variety of waste products which are generally discharged into water courses. Some of these wastes are poisonous and the effects of others are obscure. Although some of the wastes have been known since antiquity, many of them are quite recent. As the technology develops, newer types of wastes are formed. Organic compounds constitute a larger proportion of these wastes which are destroyed only slowly by bacteria and unpleasant odours and tastes are produced and are carried along the water course for considerable distances.

The principal industries situated in all countries are paper and pulp industries, textile industries, food processing industries, chemical industries, metal industries and petroleum industries. The nature and effects of the pollutants from the effluents of these industries are discussed briefly in the following pages.

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* Activated carbon is a porous and highly adsorbent form of carbon with a very large surface area.

Paper and pulp industries

These industries not only cause air pollution but also cause a great amount of water pollution. The effluent contains stray wood chips, bits of bark, cellulose fibres and dissolved lignin in addition to a complex mixture of chemicals. About 50 per cent of the total wood used for the process is rejected as waste material. They would sink to the bottom and produce a sludge which blankets fish spawning grounds and destroys certain types of aquatic life. Fish may also be killed by irritation or by clogging of gill membranes. Bleaching liqours which contain free chlorine and sulfur dioxide are toxic to fish. The effluent may also contain methyl mercaptan, pentachlorophenol and sodium pentachlorophenate which are considered to be highly poisonous to fish. As the effluent is dark coloured, it may also interfere with the aquatic photosynthesis.

Textile industries

The effluents from textile industries are alkaline in nature and they have a higher demand for oxygen. The effluents result from the cooking and desizing of the fibres. It is reported that the treatment procedures are tedious and the cost of the treatment is also high.

Food processing industries

The wastes from food processing industries such as dairy, breweries, distilleries, meat packing industries are principally organic in nature and they are putrescible. Hence the receiving waters may be depleted of oxygen. In addition to fats, proteins and organic wastes, some of the pathogenic organisms are also released through the effluents from slaughter houses, stock yards and packing plants. Sugar industries, breweries and distilleries discharge wastes containing nitrogen, sugar, proteins, fermented starches. These wastes will have a higher B.O.D. and should be treated before discharge.

Chemical industries

This category includes, acid manufacturing industries, alkali manufacturing industries, fertilizer industries, pesticide industries, and many other industries that manufacture organic and inorganic chemicals. Many of the industrial effluents contain acids. These wastes should be neutralized before discharge. Rayon manufacturing industries and DDT manufacturing industries have a higher proportion of acids which have corrosive effects. The production of 2,4-D releases dichlorophenol into the water. The effluent from fertilizer industries contain phosphorus, fluorine, silica and large amounts of suspended solids.

Metal Industries

The metal industries usually discharge effluents containing copper, lead, chromium, cadmium, zinc, etc.. which are toxic to human beings and aquatic life. The effluents also contain acids, oils, greases and cleansing agents. The wastes from steel mill have ore, coke, limestone, phenol, cyanogen, oils, and fine suspended solids. Neutralisation of these acidic effluents leads to a large volume of sludge which once again becomes a nuisance.

Petroleum Industries

Oil refineries and petrochemical plants produce a mixture of wastes containing hydrocarbons, phenolic compounds and numerous organic and inorganic sulphur compounds. They impart objectionable tastes and odours to the receiving waters.

Other Industries

This category includes industries that are not discussed separately. For example, tanneries, soap and synthetic detergent industries, glass industries, electroplating industries etc. All of these industries produce a wide variety of water pollutants. Discussions regarding the nature and effects of these pollutants are beyond the scope of this book (Refer Chapter V "Radio-active Pollution" for radio-active wastes).

Some of the important industries and the principal constituents of the effluents are tabulated as follows :

Industries	Important constituents of the effluent
1. Acetate rayon	Acetic acid
2. Aluminium anodizing	Chromium
3. Atomic energy plants	Fluorides
4. Battery manufacture	Lead, mineral acids
5. Bleaching industries	Sulfite, free chlorine

Industries	Important constituents of the effluent
6. Breweries	Sugars, mineral acids
7. Ceramic plants	Fluorides
8. Chemical manufacture	Mineral acids, phenols, ammonia organic acids such as tartaric acid, nitrocompounds
9. Chocolate and sweet industries	Sugars
10. Chrome-tanning	Chromium
11. Copper pickling	Copper, mineral acids
12. Copper plating	Copper
13. Cotton mercerizing	Alkalis
14. Cotton and straw kiering	Alkalis
15. Cuprammonium rayon manufacture	Copper
16. Dairies	Sugars
17. DDT manufacture	Mineral acids
18. Distilleries	Organic acids
19. Dyeing industries	Tartaric acid
20. Dye manufacture	Phenolic compounds
21. Engineering works	Fats, oils and grease
22. Explosive factories	Nitrocompounds
23. Fertilizer plants	Phosphates, fluorides
24. Food processing	Starch
25. Galvanizing industries	Zinc
26. Gas and coke manufacture	Ammonia, cyanides, sulfides, phenols
27. Glass etching	Fluorides
28. Iron pickling	Iron, mineral acids
29. Laundries	Alkalis, free chlorine, fats, oils and grease
30. Leather manufacture	Tartaric acid
31. Metal cleaning	Cyanides
32. Metal refineries	Fluorides
33. Oil refineries	Mereaptans
34. Paint manufacture	Lead
35. Paper mills	Free chlorine

36. Penicillin manufacture	Formaldehyde
37. Peroxide bleaching of textiles	Hydrogen peroxide
38. Petro-chemical industries	Hydrocarbons
39. Petroleum refineries	Hydrocarbons, phenols, fats, oils and grease
40. Photo-engraving	Mineral acids
41. Photography	Silver
42. Pickle manufacture	Acetic acid
43. Plating industries	Copper, chromium, nickel, cadmium, zinc and silver
44. Preserve manufacture	Sugars
45. Pulp mills	Mereaptans
46. Rocket motor testing	Hydrogen peroxide
47. Rubber processing	Zinc
48. Saw mills	Tannic acid
49. Scrubbing of flue gases	Fluorides
50. Sheep-dipping	Arsenic, phenols
51. Soft-drinks manufacture	Citric acid
52. Sugar factories	Sugars
53. Sweets manufacture	Sugars
54. Synthetic resin manufacture	Phenols, formaldehyde
55. Synthetic rubber factories	Hydrocarbons
56. Tanneries	Sulfides, chromium, phenols, tannic acid
57. Tar distilleries	Phenols
58. Textile bleaching	Free chlorine, sulfites
59. Textile industries	Mineral acids, fats, oils and grease
60. Transistor factories	Fluorides
61. Viscose film manufacture	Sulfites
62. Viscose rayon manufacture	Sulfides, zinc
63. Wall-paper manufacture	Starch
64. Wood processing	Sugars
65. Wood pulp processing	Alkalis and sulfites
66. Wool scouring	Alkalis, fats, oils and grease.

Harmful effects of Industrial Effluents

1. Industrial effluents impart colour and turbidity to the receiving waters.

2. They undergo putrefaction to form evil odours and objectionable tastes. Moreover, the effluent itself may cause tastes and odours because of the constituents present in them.
3. Acids and alkalis present in the effluent make the water corrosive.
4. Heavy metals and other toxic materials may kill fish, and other aquatic life, animals and vegetables.
5. The toxic substances may kill the bacteria and the natural purification processes of the streams are thus inhibited.
6. Some of the trade wastes may contain pathogenic bacteria. For example, tannery wastes may contain the pathogen Anthrax bacilli. (However, almost all trade wastes are reported to be free from pathogens).
7. Heated effluents discharged into rivers may cause harmful rise in the temperature of the stream and there is a possibility of the eco-system of the water course being altered.
8. Certain mineral constituents can cause excessive hardness to a water body and then the water becomes unsuitable for both domestic and industrial purposes.

Treatment and Disposal of Industrial Effluents

The treatments used for industrial effluents are the same as that of sewage. All types of treatments, viz., primary treatment, secondary treatment and tertiary treatment are necessary for industrial wastes also. An advantage in the treatment of trade effluent is that the quality of waste water is uniform and predictable and the exact pollutants are known. Hence it is often possible to choose a well-suited treatment for a particular effluent. In general, the treatments may be classified into two categories and studied as follows :

Effluents with organic impurities :

Waste waters from food processing industries, dairies, breweries, distilleries, paper mills, textile industries and organic chemicals manufacturing industries primarily contain organic impurities and hence they are generally subjected to conventional biological treatments. Before biological treatments, there are many primary treatments to be given. If the organic matter present in the effluent is easily putrescible aeration has to be done. If inorganic contaminants are also present in higher quantities, then they have to be removed. Hot effluents should be cooled either by air or by dilution. Strongly acidic or alkaline wastes have to be neutralised. Wastes containing inorganic toxic materials such as heavy metals should be removed by chemical treatment. Settleable organic matters may be precipitated in order to make the biological treatment effective. Suspended organic pollutants and colloidal impurities can also be removed by coagulation. After all these processes, the effluent may be subjected to biological processes.

Activated-sludge and trickling-filter treatment are the biological processes of choice. If the effluent contains higher amounts of dissolved organics, special allowances have to be made. When the effluent is devoid of microorganisms, suitable microorganisms have to be introduced and special provision for nutrients should also be made.

If enough land is available, lagoons may be constructed which can serve many purposes; equalization, settling, self-neutralization, promotion of spontaneous and induced chemical reactions, and both aerobic and anaerobic biological degradation. However, if these lagoons are not well operated, they may become over-loaded and give off bad odours.

Effluents with inorganic impurities :

The effluents from chemical manufacturing industries, electroplating industries and others of this type contain primarily inorganic substances. These wastes are mainly subjected to chemical treatment only. Most of the wastes are acidic and they are neutralized by lime (calcium oxide). Lime is the most commonest neutralising agent, since it is cheaper and more effective. Just as acid wastes, alkaline wastes should also be neutralized. Waste waters from tanneries, textile plants and chemical industries are normally treated with sulfuric acid. In general, whether the waste is acidic or alkaline it should be neutralized to a pH such that it can directly be discharged into the receiving stream. Coagulation may be employed for certain wastes to separate suspended matter, oily materials and precipitable dissolved substances. Heavy metals may be precipitated by raising pH or by using suitable precipitating agents.

Chemical oxidation is employed for certain types of waste waters. For example, cyanide wastes are subjected to chlorination under alkaline conditions. Ozone is another effective oxidizing agent. Phenolic wastes are oxidized by ozone. Chemical reduction is also applied to some wastes. For example, chromium is removed from electroplating wastes and anodizing wastes by reduction with sulfur dioxide. Sulfur dioxide is the common reductant, while others such as ferrous sulfate are also used for some wastes.

Most of the waste waters can be treated by chemical means. But, however, there are some impurities for which removal processes are neither known nor forseeable. For example, the brine wastes that are released from the manufacture of chemicals and in petroleum production can never be treated since the chloride ions can neither be removed nor destroyed with reasonable economy. This is the same case with radio-active wastes also. The possible means of disposing these wastes are : (i) concentration and dumping at sea, and (ii) diffusion into an underground aquifer of non-potable water. These methods, however, are not satisfactory and newer methods have to be found out.

Water Pollution : Agricultural

Modern techniques employed in agriculture and newer chemicals used have contributed much to environmental pollution, particularly to water pollution. The effects of pollution by agriculture have been dealt with from time to time in other chapters. In this section, some of the problems of water pollution associated with agriculture are discussed in detail.

Agricultural water pollution includes fertilizers, insecticides and pesticides, farm animal wastes and sediments. These pollutants can enter waterways as run-off from agricultural lands.

Fertilizers

In recent years there has been an increased use of fertilizers. Agricultural fertilizers generally contain one or more of the plant nutrients—nitrogen, phosphorus and potassium. Pollution problems can arise from excessive application rates. The fertilizers can be transmitted to ground water by leaching, and to surface waters by natural drainage and storm run-off. Nitrates are of prime concern since the presence of them in drinking water may cause methemoglobinemia in infants ("blue babies"). The nitrates are reported to be reduced to nitrites in the stomach of the babies which has a great affinity for haemoglobin of the blood and consequently it forms methemoglobin. The same process also occurs in the stomach of the ruminants and thus livestock are also affected by nitrate poisoning.

Plant nutrients contribute also to eutrophication. The enrichment of waters by nutrients is referred to as eutrophication. The plant nutrients, nitrogen and phosphorus are reported to stimulate the growth of algae and other aquatic plants. Excessive growths of these plants interfere with water uses and later they decay to produce evil odours with the resultant increase in biochemical oxygen demand.

Pesticides

Pesticides can be classified as insecticides, herbicides, fungicides, rodenticides, algaecides, molluscicides, acaricides and nematocides. *Insecticides :* Insecticides are the widely employed chemicals in controlling insects and other pests. Insecticides include chlorinated hydrocarbons, organophosphorus compounds, inorganic fluorine compounds and mercuric compounds. Among them chlorinated hydrocarbons are commonly used. DDT, BHC, dieldrin, aldrin, endrin, heptachlor, methoxy chlor, chlordane, tetradifon, mirex, and toxaphene are the important cholorinated hydrocarbons. DDT, the most commonest insecticide is least soluble in water but more soluble in fats and oils. DDT and other chlorinated hydrocarbons are reported to affect the central nervous system of both vertebrates and invertebrates. All these insecticides have a high persistence capacity (i.e.) their residues remain for longer periods unaffected. Hence they affect a large number of different species.

Among the organophosphorus compounds, the important ones are parathion, malathion and TEPP (Tetra ethyl pyrophosphate). They are highly toxic to man and animals. Most of the organophosphorus compounds are biodegradeable and they do not persist in the environment for longer periods. These compounds also affect the nervous system.

Herbicides : Herbicides are the chemicals that kill plants. Both selective herbicides and non-selective herbicides are available. Selective herbicides kill only certain types of plants, e.g., ferrous sulfate kills dandelions only. Non-selective herbicides such as sodium arsenite, sulfuric acid and certain oils kill all plants. The most commonly employed herbicides are 2, 4-D (2, 4-dichlorophenoxy acetic acid) and 2, 4-5-T (2, 4, 5-Trichlorophenoxy acetic acid). Though the herbicides are excellent weed killers, the toxicity is much high.

Fungicides : Fungicides are used to eradicate fungal disease of plants. The common fungicides include sulfur, organic mercuric compounds such as methyl mercury and copper compounds.

Rodenticides : Rodenticides are used against rodents such as rats and mice. The important rodenticides are norbormide, strychnine and sodium fluoroacetate. Norbormide is a selective toxicant far rats since it constricts the small peripheral blood vessels of rats. This type of specific action has not been exerted in other animals by norbormide.

Effects of pesticides

Almost all the pesticides in use are toxic to human beings and animals. Among them, the organophosphorus compounds are the most toxic. It is reported that sufficiently large quantities of DDT, dieldrin, aldrin and mirex are capable of inducing tumors in mice. They are also capable of producing mutations or chromosomal aberrations in plants. A report by K.D. Courtney (1970) indicates that 2, 4, 5-T (2, 4, 5-trichlorophenoxy acetic acid) is teratogenic and fetocidal in some mice. Besides, occupational exposure of these pesticides are also reported to cause impotency in man. (Refer : Espir, M.L.E., *et. al.*, "Impotence in Farm Workers using Toxic Chemicals". British Medical Journal 1 : 423-425 1970).

Since pesticides are often concentrated in food chains, reproductive abilities of fish and birds are affected. The pesticides generally affect the central nervous system of the fish. It is also reported that pesticides are the main reason for the decline in populations of several birds. The PCBs are reported to be distributed throughout the world and are being concentrated in the food chains of marine ecosystems. Recent experiments prove that the chlorinated hydrocarbons may affect photosynthesis and growth of marine phytoplankton.

A number of alternative pest control methods have been developed to eliminate the use of pesticides. However, a complete success has not yet been achieved.

Farm animal wastes

Farm animal wastes have been regarded as an important source of soil fertility. They pose serious problems of odour and water pollution. Animal wastes are a major problem since they are permitted to enter water supplies when run-off carries the wastes into water courses. The serious problem is that the wastes containing pathogenic organisms will transmit them to man. Moreover, the animal wastes cannot simply be treated as municipal sewage. Raw sewage usually may have a BOD of 200 ppm, 400 ppm COD and nitrogen 40 ppm while feedlot run-off will have 1000 ppm BOD, 8000 ppm COD and 700 ppm nitrogen. Hence municipal sewage treatment methods are not applicable to farm animal wastes. Further, when feedlot run-off occurs, it can produce heavy pollution in receiving streams and massive fish kills may occur.

Control of animal wastes is a problem of utmost importance and biological treatments are reported to be satisfactory in the control. However, simpler methods have to be found out in future to eliminate the difficulties encountered in biological processes.

Sediments

Sediments are soil and mineral particles washed from the land by storms and flood waters, from croplands and overgrazed pastures. Sediments cause many ill-effects. They fill stream channels and reservoirs and reduce the amount of sunlight available to aquatic plants. They also blanket fish nests, spawn and food supplies and thus reduce fish and shell-fish populations. It is estimated that the amount, of suspended solids from surface run-off is always greater than that of sewage discharge.

Conclusion

There are so many possibilities for water pollution through agricultural practices. It should be noted, however, that the extent of water pollution by agriculture is much less when compared with that of sewage and industrial effluents.

Water pollution : measurement of water quality

The control of water pollution necessarily needs quantitative measurements of water pollution. Without knowing the substances, and their quantities in water, specific treatment cannot be chosen. However, the measurement of water quality is a tedious one and some experience in water analysis is necessary. The quantitative methods cannot be discussed in detail since it constitutes a separate volume and only an outline of the procedures have been given in the following pages. (For detailed methods and procedures, readers are advised to refer "Standard Methods for the Examination of Water and Waste Water"—14th edition, 1974 ; American Public Health Association).

A. Chemical and physical examination

I. Chemical substances indicative of pollution

1. Nitrogen : The nitrogen present in saline constituents is referred to as ammoniacal nitrogen and nitrogen present in organic constituents as proteins, amino acids and amines is termed as albuminoid nitrogen. Both these two can be estimated separately as ammonia using Nessler's reagent. First, the sample of water is distilled after adding phosfate buffer (pH 7.4) and the distillate contains ammoniacal nitrogen. The distillation is continued with the addition of alkaline potassium permanganate and this second distillate contains albuminoid nitrogen.

Total organic nitrogen (Kjeldahl method) : Total organic nitrogen may be determined by digestion of the sample after the removal of free ammonia by distillation. The ammonia formed after digestion is distilled and titrated with a standard acid. Digestion is usually carried out using sulfuric acid and copper sulfate catalyst. After digestion, sample is neutralised with a strong alkali and then distilled. Total organic nitrogen may also be calculated as the difference between the value obtained for total Kjeldahl nitrogen and that for free ammonia.

Nitrite nitrogen : The nitrite nitrogen is determined through the formation of a reddish purple azo dye produced at pH 2.0—2.5 by the coupling of diazotised sulfanilic acid with 2—naphthylamine hydrochloride.

2. Biochemical oxygen demand : BOD is a measure of the amount of oxygen required by bacteria and other microorganisms while stabilizing decomposable organic matter. The dissolved oxygen present in the sample is estimated by the famous Winkler method with some modifications. The basic principle is the oxidation of manganous hydroxide in an alkaline solution. On acidification in the presence of an iodide, the manganic hydroxide dissolves and free iodine is liberated in an amount is equivalent to the oxygen originally dissolved in the sample. The liberated iodine is titrated with sodium thiosulfate solution using starch as indicator.

3. Chemical oxygen demand (Total organic matter) : Although BOD test indicates the amount of total organic matter, there are so many drawbacks. To compensate them, chemical oxygen demand test can be carried out. Actually it is a chemical oxidation of the sample with potassium dichromate in which all the organics are oxidised. A known amount of potassium dichromate is added to a measured amount of sample and the mixture is boiled with concentrated sulfuric acid. After boiling, the excess dichromate is measured titrating it against ferrous ammonium sulfate using ferroin as indicator. The difference between the chromate originally added and the chromate remaining is the chromate used for oxidizing the organics.

II. Toxic chemical substances

1. Arsenic : After concentration of the sample, arsenic is liberated as arsine (AsH_3) by zinc in acid solution in a Gutzeit generator. The generated arsine is absorbed in sodium hypobromite solution and oxidised to pentavalent state. Ammonium molybdate in acid solution in the presence of hydrazine sulfate as a reducing agent, produces a blue colour with the oxidised arsine.

2. Cadmium : Cadmium reacts with dithizone to form an intense red complex with dithizone. When the extraction is carried out from a strongly basic solution silver mercury, copper and cobalt only interfere. These can be removed by preliminary extractions.

3. Chromium . Hexavalent chromium reacts with s-diphenyl carbazide to form a reddish violet colour in a slightly acid solution which can be measured visually or photometrically.

4. Copper : Cupric ions form a yellow coloured chelate when react with "cuprethol" (bis-2-hydroxy ethyl) dithiocarbamate at a pH of 5 to 6. Hydrochloric acid and sodium acetate are used for buffering. Pyrophosfate is usually added to eliminate the interference from iron.

*5. Cyanide :*The CN ion in the sample is distilled as HCN and then is converted to cyanogen chloride CNCl by reaction with chloromine-T at a pH less than 8. After the reaction is complete CNCl forms a blue dye on the addition of pyridine-pyrazolone reagent, which can be estimated colorimetrically.

6. Lead : Dithizone in chloroform completely extracts lead from a basic solution containing citrate, forming metal complex which is soluble in chloroform and imparts a red colour to it.

7. Phenolic compounds : Phenolic substances react with 4-amino-antipyrine to form an antipyrine dye at a pH of 10.0±0.2 in the presence of ferricyanide. The dye can be extracted from aqueous solution using chloroform and can be measured photometrically.

8. Selenium : Selenium is liberated from its solution as selenium bromide by distillation with hydrobromic acid and bromine. The selenium bromide in the aqueous distillate becomes selenious acid. The excess bromide is reduced by treatment with sulfur dioxide and then the selenious acid is reduced to elemental selenium using hydroxyl amine hydrochloride as the reducing agent. The selenium is precipitated in the form of a stable red colloidal suspension which can be determined visually or photometrically.

Alternatively, selenium can be determined by "Diamino benzidine method." Refer "Standard Methods", 13th edition—APHA, 1971.)

9. Zinc : Zinc reacts with dithizone to form a red zinc dithizonate which can be separated from reacting metals by adjusting the pH to 4-5.5, and then measured photometrically.

10. Other toxic substances : (i) Surfactants (detergents) : Anionic surfactants react to form a blue coloured salt with methylene blue. This salt is soluble in chloroform and can be extracted and measured at a wavelength of 625 mls.

(ii) Oil and grease : Dissolved or emulsified oil or grease is extracted from water by using organic solvents. After extraction, the solvent may be evaporated and the weight of the oil can be found out.

III. Chemical substances affecting health

1. Fluoride : Fluoride is estimated by a colorimetric method which is based on the reaction between fluoride and a zirconium-dye lake. Fluoride, actually reacts with the dye dissociating a portion of it into a colourless complex anion, and the dye. As the concentration of fluoride increases the colour becomes lighter or different in hue.

2. Nitrate : Nitrate reacts with 2, 4-phenoldisulfonic acid to form 6 nitro-2, 4-phenoldisulfonic acid which upon treatment with strong alkali is converted into a yellow salt and is employed for the colorimetric estimation.

IV. Chemical substances affecting potability

1. *Substances affecting the colour* : The "true colour" of a water sample is due to the substances which are present as fine colloids or in solution (and not as suspended matter). The true colour can be estimated by visual comparison with platinum-cobalt standard colour solution.

2. *Turbidity* : The standard method for the determination of turbidity is the "Jackson Candle Method". Suspensions standardised by this method are used to standardise turbidity meters by which the turbidity of a water sample is measured.

3. *Odour* : Shake about 250 ml of the sample in a 500 ml wide-mouth Erlenmeyer flask at 20° C and sniff the odour. This is cold odour quality. To find out the hot odour quality, pour about 250ml sample in a 500 ml wide-mouth Erlenmeyer flask and heat to about 58-60°C. Slip the watch glass aside and sniff the odour.

4. *Residue* : An appropriate volume of the sample is chosen and evaporated in a platinum dish on a water bath. From the weight of the residue calculate the total solids per litre. If suspended matters are present, filter the sample and evaporate the sample and weigh it. This is the weight of total dissolved solids. The differences between total solids and total dissolved solids is the weight of suspended matter.

5. *Hydrogen ion concentration* (pH) : The pH of a sample can be determined by using pH meters or by colorimetric method using suitable indicator solutions.

6. *Calcium* : Calcium is determined by titration with standard EDTA solution using murexide indicator after masking magnesium.

7. *Magnesium* : Magnesium can be estimated by gravimetric method using diammonium hydrogen phosphate as the precipitating agent. Before precipitation calcium must be removed from the sample. Alternatively, the difference between total hardness and calcium hardness also gives the magnesium concentration.

8. *Iron* : Iron is brought into solution by boiling with acid and then reduced with hydroxyl amine hydrochloride to ferrous state which on treatment with 1, 10-phenanthroline forms a red

complex and is measured colourimetrically.

9. *Manganese* : Persulfate oxidises soluble manganous compounds to permanganate the colour of which is measured and the concentration of manganese is thus calculated. Silver nitrate is added as a catalyst in the reaction.

10. *Chloride* : Chloride is estimated by titration with standard silver nitrate in neutral or weakly alkaline solution using potassium chromate as indicator.

11. *Sulfate* : Sulfate in a water sample is converted to insoluble barium sulfate using barium chloride and is estimated gravimetrically.

B. Bacteriological examination

There are many pathogens in water and each has a separate detection procedure. The concentration of these organisms, however, is small to be measured. Hence indicator organisms are used to detect the pathogens. The indicator most often used is a group of microbes called coliforms. These are the organisms normally found in the digestive tracts of warm-blooded animals and are plenty in number and easy to detect. However, the presence of coliform organisms does not necessarily mean that pathogens are present. It simply means that there might be. A high coliform count is thus suspicious and the water (though chemically safe) should not be consumed.

One popular and simplest method of measuring coliforms is called the Most Probable Number. This test is based on the fact that coliform organisms ferment the lactose and the broth becomes cloudy and some amount of gas is liberated. The production of gas can be tested by placing a small tube (known as Durham tube) upside down inside a larger tube containing lactose broth. After inoculation, (i.e., introduction of samples into the broth) the broth tubes are incubated for 48 hours at 37±.2°C. After incubation, if gas is produced, it will be collected in the small tube which indicates the presence of coliform organisms.

Actually, 10 ml, 1.0 ml and 0.1 ml of the samples are introduced in three sets of 5 tubes each containing lactose broth, and are incubated. After 48 hours the number of positive tubes (i.e., the tubes in which gas is produced) are counted and the actual number of coliform organisms present in 100 ml of the sample is found out

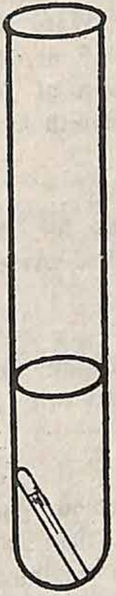

Fig. 10 Lactose broth fermentation tube showing fermentation of the lactose with the production of acid and gas.

from the MPN index (for MPN Index, refer "British Ministry of Housing & Local Government", Fourth edition, 1969—Report, 1971).

(To know further details and procedures of bacteriological and virological examination, the readers are directed to refer "Medical Microbiology" by Cruick Shanks—12th edition, volumes I & II, ELBS & Churchill Livingstone, London, 1975 and "Standard Methods for the Examination of Water and Waste Water"—14th edition, American Public Health Association, 1974).

C. Biological examination

Biological examination is actually the microscopical examination of water. The procedures include a qualitative analysis of the types of organism present, and a quantitative estimation of their number. In addition, particulate organic and inorganic matter will also be detected. A detailed study of biological examination is beyond the scope of this book and the readers are asked to refer, "Fresh Water Biology" by Ward and Whipple" (edited by W.T. Edmondson), John Wiley & Sons, New York, 1976 and "Standard Methods for the Examination of Water and Waste Water"—14th edition, American Public Health Association, 1974.

D. Radiological Examination

Refer "Standard Methods for the Examination of Water and Waste Water"—14th edition—American Public Health Association, 1974.

International Standards of Quality for Water Sources*

(Prescribed by World Health Organisation)

Physical Quality

The limiting value for colour should be set at 300 units, on the basis that a value of less than 300 units indicates an acceptable quality for treatment and anything over 300 units indicates that special treatment may be needed to provide water meeting the drinking-water standards.

Regarding turbidity, no specific figures are given, since the problem of turbidity and the treatment needed is one that has to be decided for each individual case and cannot be subject to a general limit.

Chemical Quality

The chemical components of water are classified in four groups : (1) those compounds affecting potability; (2) those having definite effects upon health; (3) those components that are definitely toxic and whose presence is greater than the limiting amounts would be sufficient grounds for rejecting the water as a source of public supply; and (4) chemical indicators of pollution. The recommended standards for each of these groups are given below :

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* Reproduced with the kind permission of WHO, from "International Standards for Drinking Water", Second Edition, 1963.

1. **Compounds affecting the potability of water**

Substance	*Maximum allowable limit*
Total dissolved solids	1500 mg/l
Iron	50 mg/l
Manganese (assuming that the ammonia content is less than 0.5 mg/l)	5 mg/l
Copper[a]	1.5 mg/l
Zinc[a]	1.5 mg/l
Magnesium plus sodium sulfate	1000 mg/l
Alkyl benzyl sulfonates (ABS : Surfactants)[b]	0.5 mg/l

2. **Components hazardous to health**

Substance	*Maximum allowable limit*
Nitrate as NO_3	45 mg/l
Fluoride	1.5 mg/l

3. **Toxic substances**

Substance	*Maximum allowable limit*
Phenolic substances	0.002 mg/l
Arsenic	0.05 mg/l
Cadmium	0.01 mg/l
Chromium	0.05 mg/l
Cyanide	0.2 mg/l
Lead	0.05 mg/l
Selenium	0.01 mg/l
Radio nuclides (gross beta activity)	1000 bbc/l

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[a] These are limiting values for raw water quality and for that reason are lower than the allowable limits for drinking water, where the presence of these metallic substances would probably be the result of the aggressive action of the water on service pipe metals.

[b] This value has been established on the basis of the maximum sensitivity of the presently accepted analytical procedures.

4. Chemical indicators of pollution

Indicator	*Minimum limit of pollution*
Chemical oxygen demand (COD)	10 mg/l
Biochemical oxygen demand (BOD)	6 mg/l
Total nitrogen exclusive of NO_3	1 mg/l
NH_3	0.5 mg/l
Carbon chloroform extract (CCE : Organic pollutants)[c]	0.5 mg/l
Grease	1 mg/l

5. Bacteriological standards

Classification	*MPN/100 ml coliform bacteria*[*]
(i) Bacterial quality applicable to disinfection treatment only	0-50
(ii) Bacterial quality requiring conventional methods of treatment (Coagulation, filtration, disinfection)	50-5000
(iii) Heavy pollution requiring extensive types of treatment	5000-50000
(iv) Very heavy pollution, unacceptable unless special treatments designed for such water are used; sources to be used only when unavoidable	Greater than 50000

6. Biological standards

It is impossible at the present time to establish definite biological parameters of the quality of water sources. Thus the same conclusions apply here as given for drinking water.

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[c] Any amount greater than 0.2 indicates the necessity for further analytical determinations of the causative material.

[*] When more than 40% of the number of coliform bacteria represented by the MPN Index are found to be of the faecal coliform group, the water source should be considered to fall into the next higher category with respect to the treatment required.

7. Radiological standards

Water from sources to be used for the production of public water supplies should be examined routinely and as great a frequency as possible for radioactive pollution. The amounts of radio-activity detected in a water source should be no greater than can be reduced by the selected methods of treatment to values which fall within the limits established for drinking water.

International Standards for Drinking Water*

(Prescribed by World Health Organization)

1. Standards of Bacteriological Quality

Treated water : In 90 per cent of the samples examined throughout any year, coliform bacteria shall not be detected or the MPN index of coliform microorganisms shall be less than 1.0. None of the samples shall have an MPN index of coliform bacteria in excess of 10. In any instance in which two consecutive samples show an MPN index of coliform bacteria in excess of 8, an additional sample, or samples from the same sampling point should be examined without delay.

When the micro-filter technique is used, the arithmetic mean of numbers of coliform group organisms shall be less than 1 per 100 ml, and shall not exceed 4 per 100 ml in two consecutive samples or in more than 10 per cent of the samples examined.

Untreated water : In 90 per cent of samples examined throughout any year, the MPN index of coliform microorganisms should be less than 10. None of the samples should show an MPN index greater than 20. Not more than 40 per cent of the number of coliform microorganisms shown by the MPN index shall be faecal coliform bacteria.

An MPN index of 15 or more should not be permitted in consecutive samples. In any instance in which two consecutive samples show an MPN index of coliform organisms greater than 10, an additional sample, or samples from the same sampling point should be examined inmmediately.

When the micro-filter technique is used in the examination of water, the arithmetic mean of the numbers of coliform bacteria determined shall be less than 10 per 100 ml and shall not exceed 20 per 100 ml in two consecutive samples or in more than 10 per cent of the samples examined.

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* Reproduced with the kind permission of WHO, from "International standards for Drinking Water" Second Edition, 1963.

2. Standards of Chemical and Physical Quality

i) Toxic substances

Substances	*Maximum allowable concentration* *mg/l*
Lead	0.05
Arsenic	0.05
Selenium	0.01
Chromium (Cr hexavalent)	0.05
Cyanide	0.2
Cadmium	0.01
Barium	0.10

The presence of any of these substances in excess of the concentrations quoted should constitute grounds for the rejection of the water as a public supply for domestic use.

(ii) Substance which may affect health

There are certain chemical substances which if present in drinking water at concentrations greater than definite limits, may be injurious to health. Some of these chemical substances are regarded as essential constituents in drinking water and, if they are not present at sufficient concentration levels, human health is affected adversely.

(a) Fluorides : Fluorides occur naturally in many public water supplies and, if present in drinking water in excess of 1.0-1.5 mg fluorine per litre, they may give rise to dental fluorosis in some children. When present in much higher concentrations, they may, eventually, cause endemic cumulative fluorosis with resultant skeletal damage in both children and adults.

In assessing the safety of a water supply with respect to the above limits of fluoride concentration, special consideration should be given to the total daily fluoride intake by the individual. Apart from variations in climatic conditions, it is well known that in some areas certain food substances contain fluorides; consequently, due attention should be given to both these factors. It should be emphasized, therefore, that in those areas where fluoride containing foods are ingested, the lower limit of the above concentration range should be a guiding factor to the chemical quality of the water.

Fluoride is also regarded as an essential constituent of drinking water, particularly with regard to the prevention of dental caries in children. If the fluoride concentration in the drinking water of a community is less than 0.5 mg/1, a high incidence of dental caries is likely to occur. To prevent the development of dental caries in children, a number of communal water supplies are fluoridated to bring the fluorine concentration to 1.0 mg/l.

(*b*) *Nitrates* : Nitrates are dangerous to human health only in some infants under one year of age. The ingestion of water which contains nitrates in excess of 45 mg/1 (as NO_3) may give rise to infantile methemoglobinaemia.

In view of the small quantity of water consumed by infants directly as drinking water, or indirectly as prepared food, it should not be difficult to find an alternative source of water with low nitrate content.

From the sources available, no single and economic method for the removal of excessive amounts of nitrates from water is found. It is necessary for health authorities, therefore, in areas where nitrate content of water is known to be in excess of the limiting concentrations, to be vigilant and to warn the population of the potential dangers of using the water for infant feeding and to inform them of alternative sources of water that may be used with safety.

(*iii*) *Chemical substances affecting the potability of water*

In view of the wide variations in the chemical composition of water in different parts of the world, rigid standards of chemical quality cannot be established. The limits thereafter designated "acceptable" apply to a water that would be generally acceptable by consumers; values greater than those listed as "allowable" would markedly impair the potability of the water.

However, these limiting concentrations are indicative only and can be disregarded in specific instances.

Substance	*Maximum acceptable concentration*	*Maximum allowable concentration*
Total solids	500 mg/1	1500 mg/1

Substance	*Maximum acceptable concentration*	*Maximum allowable concentration*
Colour	5 units*	50 units*
Turbidity	5 units**	25 units**
Taste	Unobjectionable	—
Odour	Unobjectionable	—
Iron (Fe)	0.3 mg/1	1.0 mg/1
Manganese (Mn)	0.1 mg/1	0.5 mg/1
Copper (Cu)	1.0 mg/1	1.5 mg/1
Zinc (Zn)	5.0 mg/1	15 mg/1
Calcium (Ca)	75 mg/1	200 mg/1
Magnesium (Mg)	50 mg/1	150 mg/1
Sulfate (SO_4)	200 mg/1	400 mg/1
Chloride (Cl)	200 mg/1	600 mg/1
pH range	7.0-8.5	Not less than 6.5 or greater than 9.2
Magnesium+Sodium sulfate	500 mg/1	1000 mg/1
Phenolic substances (as phenol)	0.001 mg/1	0.002 mg/1
Carbon chloroform extract (CCE : Organic pollutants)	0.2 mg/1	0.5 mg/1***
Alkyl benzene sulfonates (ABS : Surfactants)	0.5 mg/1	1.0 mg/1

3. Biological Requiremets

Refer pages from 31 to 35, "International Standards of Drinking Water"—WHO, Geneva, 1963.

4. Radiological Requirements

The following limiting values are tentatively established to serve as a guide to the maximum acceptable limits in drinking water as supplied to consumers for life time use for large populations :

	Maximum limits of concentration
Strontium-90	30 u u c/litre

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[*] Platinum-cobalt scale

[**] Turbidity units

[***] Concentrations greater than 0.2mg/l indicate the necessity for further analyses to determine the causative agent.

	Maximum limits of concentration
Radium-226	10 u u c/litre
Gross beta concentration (in the absence of strontium-90 and alpha mitters)	1000 u u c/litre

The limiting values for radioactivity given above are not to be taken as values that, if exceeded, would render the water unfit for drinking purposes. They are merely intended to indicate that, if the levels are lower than those given, then the water is safe for use without further investigation; if, however, the levels exceed these figures, radio-chemical analysis will be required to determine the nature of the radionuclides present before deciding the safety of the water for use as a public supply. The figures given are intended to include naturally occurring radioactivity, as well as any radioactivity that may reach the water from effluents and fall out. It is at least possible that naturally occurring radioactivity may be just as dangerous to health as that which may be discharged in effluents from nuclear reactors or other sources, and it is considered that in drinking water, it is the total radioactivity that is of importance from the point of view of possible danger to the health of the community. It is appreciated that the figures given for radioactivity are near the limits of measurements by the instruments at present in use.

Standards of Quality for Drinking Water*

(Prescribed by Indian Council of Medical Research, 1975)

1. Physical and chemical quality

Substances	*Highest desirable level*	*Maximum permissible level*
Substances affecting the colour, TCU[1]	5 units	25 units

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* Reproduced with the kind permission of the Indian Council of Medical Research from their publication : "Manual of Standards of Quality for Drinking Water Supplies". 1975

The values prescribed are to be considered individually and may not bear correlation with each other.

[1] True colour unit, platinum-cobalt scale.

Substances	*Highest desirable level*	*Maximum permissible level*
Substances causing odour	Unobjectionable	Unobjectionable
Substances altering the taste	Unobjectionable	Unobjectionable
Turbidity, JTU[2]	5 units	25 units
Dissolved solids	500 mg/l	1500 mg/l*
pH range	7.0 to 8.5	6.5 to 9.2
Total hardness	300 mg $CaCO_3$/l	600 mg $CaCO_3$/l
Calcium	75 mg Ca/l	200 mg Ca/l
Magnesium	Not more than 50 mg/l Mg, if there are 200 mg/l sulfates; if there is less sulfate, magnesium up to 100 mg/l, Mg may be allowed at the rate of 1 mg/l, Mg for every 4 mg/l decrease in sulfates	100 mg Mg/l
Copper	0.05 mg Cu/l	1.5 mg Cu/l
Iron	0.1 mg Fe/l	1.0 mg Fe/l
Manganese	0.1 mg Mn/l	0.5 mg Mn/l
Chloride	200 mg Cl/l	1000 mg Cl/l
Sulfates	200 mg So_4/l	400 mg SO_4/l
Nitrate	20 mg NO_3/l	**
Fluoride	1.0 mg F/l	1.5 mg F/l
Phenolic compounds	0.001 mg phenol/l	0.002 mg phenol/l

Toxic substances

Substances	*Upper limit of concentration*
Arsenic	0.05 mg As/l

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[2] Jacson Turbidity Unit.

* Dissolved solid relaxable up to 3000 mg/l in cases where alternate sources are not available within reach.

** More information is required to prescribe a value but in no circumstances should the level exceed 100 mg NO_3.

Substances	*Highest desirable limit*	*Maximum permissible level*
Cadmium		0.01 mg Cd/1
Lead		0.1 mg Pb/1
Mercury		0.001 mg Hg/1
Selenium		0.01 mg Se/1
Cyanide		0.05 mg CN/1

2. Radiological requirements

	Maximum permissible limit of radioactivity
Gross alpha activity	3 pCi/1
Gross beta activity	30 pCi/1

Excessive nitrates in drinking water may cause mathaemoglobinaemia in some young infants. No simple or economical method for removing nitrates from water is available. Hence it is recommended that in the case of water supplies containing nitrate in excess of the limiting concentrations, the consumers should be advised as to the potential danger of using the water for infant feeding.

IV

Soil and Land Pollution

SOIL POLLUTION usually results from the disposal of solid and semi-solid wastes from agricultural practices and from insanitary habits. Fall out from atmospheric pollution also contributes to soil pollution. The problem of land pollution differs from water and air pollutions in the respect that the pollutants remain in place for relatively longer periods. Year by year solid wastes are increasing considerably from country to country depending upon their living standards. Rapid urbanisation with the consequent increase in buildings has resulted in the reduction of lands for the wastes to be disposed. Utilization of land, now creates another problem, i.e., disposal of solid wastes other than land has led once again to air pollution and water pollution. Discharge of these wastes into water course increases water pollution and improper incineration causes severe air pollution. However, disposal on land also creates public health problems. Dumping of industrial and municipal wastes causes toxic materials to be leached and seep into the soil which affects the ground water course. Agricultural practices introduce pesticides, fertilizers and manures to land resulting in both biological and chemical contamination. Apart from all these, direct pollution of the land by pathogenic organisms is also of major importance. Thus the soil is heavily polluted day by day by hazardous materials and microorganisms enter the food chain or water and are consequently ingested by man.

The problem of soil pollution may be studied under the following heads :

1. Soil pollution by industrial and urban wastes.
2. Soil pollution by agricultural practices.
3. Soil pollution by radio-active materials.
4. Soil pollution by biological agents.

Soil pollution by industrial and urban wastes

Disposal of industrial solid wastes is the major source of soil pollution by toxic chemicals. The industrial wastes are mainly discharged from coal and mineral mining industries, metal processing industries and engineering industries. They contain toxic metals such as lead, copper, etc., Urban wastes comprise both commercial and domestic wastes including dried sludge of sewage. In general, all the urban solid wastes are referred to as "refuse". The refuse contains garbage (food wastes), rubbish materials such as paper, glasses, metallic cans, plastics, fibres, residues from home fuels, street sweepings, rubbles and abandoned vehicles. It has been reported that about 50 per cent of the raw meterials ultimately become waste products in industry and about 15 per cent of it are toxic or deleterious. In United Kingdom it has been estimated that about 20 million tons are disposed off as industrial waste and about 15 million tons as domestic refuse. About 90 per cent of domestic refuse is directly tipped on to land. Industrial solid wastes are also tipped on land and the disposal of all types of solid wastes results in increasing amounts of soil pollution. As a result hazardous chemicals can enter into surface or ground water or poison the soil or crops.

The dumping of solid wastes not only creates aesthetic problems but also public health problems. Solid wastes may or may not cause diseases in man but they are hazardous to health. It is reported that about 25 human diseases are associated with the solid wastes. There is an increase in the number of rats and flies due to dumping of wastes. These rats which are carriers of insects and other bio-organisms are the ones responsible for plague. The flies which carry pathogenic organisms cause diseases such as dysentery, diarrohea, etc. It is estimated that about 70,000 flies can be produced in one cubic foot of garbage. The health aspects of solid wastes are numerous, and their discussion of them is beyond the scope of this book.

Soil pollution by agricultural practices

Agricultural practices also pollute the soil. Many agricultural areas have now large surpluses of plant and animal wastes which when otherwise disposed will cause pollution. Since agriculture is becoming more and more intensive, increasing quantities of fertilizers, pesticides and soil conditioning agents are used. The wastes formed due to these materials cause severe land pollution problems.

Fertilizers :

Throughout the world, the use of artificial fertilizers for land has increased considerably. Though the fertilizers are used to fortify the soil, they also contaminate the soil to some extent with their impurities. Generally fertilizers are retained by the soil and the crop efficiently but there are some possibilities for the nitrate to be washed out due to the careless appliances which may affect the quality of lowland lakes or rivers. When the fertilizers are contaminated with other synthetic organic chemicals, the soil water may also be polluted.

Pesticides :

Pesticides are of great value in controlling insect-borne diseases and in the protection of crops. Among pesticides the most important are the chlorinated hydrocarbons, e.g., D.D.T., B.H.C., endrin, aldrin, dieldrin and lindane and organophosphorus compounds such as parathion and malathion. The remnants of these pesticides may be absorbed by soil particles which may contaminate root crops grown in soils. Lindane has been reported to taint carrots.

Soil conditioners, fumigants and other chemical agents :

In addition to fertilizers and pesticides, soil conditioners and fumigants, are used in agriculture. These chemical agents are reported to cause alterations in both the agricultural and horticultural lands. Organic compounds containing lead, mercury and arsenic, when applied to a land will accumulate on the soil permanently and introduce these toxic metals into plant products. Researches are being carried out to manufacture pesticides of short-lived degradable residues so that the persistence of the remnants of pesticides and their degradation products on food and forage crops may be reduced considerably.

Farming :

During the past 25 years the wastes from cattle sheds and poultries has increased to considerable extent. These wastes should be disposed of suitably on to land which conditions the soil. When the wastes are dumped into heaps many nuisances arise. These heaps become a good breeding ground for flies, insects and rodents which are the carriers of pathogenic organisms. Moreover, odour from decomposition of these organic wastes causes a serious problem for public health.

Soil Pollution by Radioactive Materials

Radioactive materials from atmospheric fall out (from nuclear explosions) and from the radioactive wastes (produced by nuclear testing laboratories and industries) reach the soil and accumulate there. Wastes from nuclear reactors contain Ruthenium 106 and Rhodium-106, Iodine-131, Barium-140 and Lanthanum-140, and Cerium-144 with Promethium-144 in addition to the primary nuclides Strontium-90 and Caesium-137. Both Strontium-90 and Caesium-137 are also produced from nuclear fission. Strontium-90 has a half life of 28 years and that of caesium-137 is 30 years. Rain make Strontium-90 and Caesium-137 to be deposited on the soil and it is held firmly to the soil by electrostatic forces. Heavy rains and soil erosion carry away the deposited strontium-90 and caesium-137 with the silt and clay. A recent report indicates that certain plants such as lichen can accumulate caesium-137 and a concentration of radionuclides in animals occur when these plants are fed. All the radionuclides deposited on the soil emit gamma radiations.

Mention has to be made regarding carbon-14. Cosmic radiations and explosion of hydrogen weapons induce neutron-proton processes by which nitrogen produces C^{14}. Carbon-14 has been given particular importance since it participates in the carbon metabolism of plants. Thus carbon-14 is introduced into plants and thereby to animals.

(Refer Chapter V, Radioactive pollution also)

Soil Pollution by Biological Agents

The excreta of human, animals and birds is the major source of soil pollution by biological agents. Digested sewage sludge which is used as a manure also causes soil pollution. In the developing countries, intestinal parasites constitute the most serious soil pollution problems. In addition to excreta, faulty sanitation, waste water and wrong methods of agriculture also induce soil pollution. The pathogenic organisms that pollute the soil may be divided into three groups and studied.

1. *Pathogenic organisms excreted by man*: This category includes organisms such as enteric bacteria, and parasitic worms. These are transmitted to man by contact with the contaminated soil or by the consumption of vegetables or fruits that are grown in contaminated soil. Thus pathogens are transmitted from man to soil and then from soil to man.
2. *Pathogenic organisms excreted by animals*: These organisms will be transmitted to man through the contact with contaminated soil, contaminated by the excreta of the infected animals. Thus disease producing organisms are transmitted from animal to soil and then from soil to man.
3. *Pathogenic organisms found naturally in contaminated soil*: Contact with this soil transmits pathogenic organisms to man.

Insanitary habits of a vast number of people has resulted in the repetition of the cycle of infection with soil-transmitted pathogens. Though modern civilization has done a great deal to mankind, there are number of people in developing countries whose habits with regard to micturition and defecation have not yet been changed. Hence there are more chances for faecal contamination to occur. Due to the high fertilizer value, human faeces are cleared from latrines and septic tanks and are disposed on to the land. Thus faecal matter which contains a variety of pathogens, transmits them to man on contact. To satisfy the need for water for irrigation, waste waters are also utilized in addition to other irrigation waters. Thus, soil and crops become contaminated, and infection to man occurs by enteric bacteria and other pathogens.

Numerous procedures have been developed to control pathogenic organisms. Recent reports indicate that many of the organisms are highly persistent and they are strongly resistant to attacking agents. For example, the eggs of Ascaris can withstand for more than two years on fields in temperate regions. Salmonella organisms persist until 70 days in soil irrigated with sewage. Hence specific treatments are necessary for the complete removal of pathogens from the sewage effluents used for irrigation purposes.

Diseases caused by soil pollution

Those bacteria which are transmitted from man to soil infect man causing bacillary dysentery, cholera, typhoid and paratyphoid fever. Flies which breed or get in contact with the contaminated soil become carriers of disease organisms. The eggs of some of the parasitic worms (helminthas) get incubated in the soil and both the eggs and larvae are infective. Some of the important soil-transmitted helminths are, Ascaris lumbricoides (round worm), Trichuris trichiura (whipworm) and Ancylostoma duodenale. The last one is said to be responsible for hookworm disease. Geohelminths are reported to suck proteins and vitamins from the nutrients of the host. This type of absorption of essential nutritional constituents results in malnutrition. Another report indicates that, loss of blood and iron in large quantities occurs due to the sucking motions of hookworms. This results in anaemia.

Some of the diseases of animals are transmissible to man, and soil plays an important role in the transmission. Leptospirosis, Q fever and Anthrax are some of the diseases of this type. Leptospirosis is a common disease in man and animals. Leptospires carried by animals are brought to the soil surface by excretion. It is estimated that about 100 million leptospires are present in the urine of animals. These leptospires excreted into water or land survive for many weeks. When human beings get in contact with the soil or water, leptospires enters the body through macerated skin or mucous membranes to cause leptospirosis. Q fever is caused by the rickettsia coxiella burnetii which is present in soil and dust. Anthrax is caused by Bacillus anthracis. The spores of Bacillus anthracis are very resistant to attack and they survive in soils and animal products for years together.

Fungi and actinomycetes—the saprophytes normally grow in soil or vegetation. They cause most serious subcutaneous and systemic mycoses. The spores may either be inhaled or penetrate skin through puncture wounds. Thus pathogens are directly transmitted to man from soil. Chromomycosis and coccidioidomycosis are the most dangerous diseases that have to be mentioned. Tetanus is another acute disease caused by clostridium tetani which is excreted by animals, particularly by horses. The tetanus bacillus grows anaerobically at the site of an injury. However, fetanus has no common occurrence.

Control of Soil and Land Pollution

As we have already seen, land is polluted largely by solid wastes from homes, farms and industry. Hence control measures include primarily the procedures for the solid wastes to be reduced and disposed safely. Disposal of solid wastes is not an easy joke since the economy involved is very high. To make the disposal of the wastes economical, recycling of materials is necessary. The waste disposal may be discussed and studied under three heads as follows :

1. Collection of wastes
2. Disposal of wastes
3. Recovery of resources.

Collection of wastes :

The wastes have to be collected from the places by trucks to disposal area. It is estimated that about 80 per cent of the total cost of solid waste management is spent for collection only. Moreover much of the time is spent only for travelling. To save time and money, transfer stations may be constructed at various places of a city so that more refuse could be brought to the nearest stations from where it could be taken away to the ultimate disposal after cramming. Another possible way is the use of pneumatic pipes. Though the initial cost and labour is more, pneumatic pipes are reported to be efficient for the collection and disposal.

Disopsal of wastes :

Dumping is a popular and an inexpensive means of solid waste disposal. However, there are many disadvantages by dumping which have already been discussed and hence other means have to be sought. Land-fill and incineration are some of the best possible ways of disposal. The land fill operation consists of depositing the refuse, compacting and 'covering it with soil to a certain height. Actually the land fill operation is a biological method of treatment. The organic materials in the municipal refuse undergo anaerobic decomposition to form carbon dioxide methane, ammonia, and a little hydrogen sulfide. The sanitary land fill is considered to be the cheapest and effective means of soild waste disposal though it has some demerits.

Though incineration is the final solution for the solid waste problem the cost of the operations is high. Moreover, incineration reduces only about 30 per cent of the total volume of the waste. The problem of disposal arises once again since the residue obtained on incineration should however be disposed. Secondly, incineration creates air pollution problems. Pyrolysis (combustion in the absence of oxygen) is also one of the acceptable means of disposal. In spite of all these methods, it has to be mentioned that no cheaper and efficient method has been found yet for the disposal of solid wastes.

Recovery of resources

Recovery of resources also known as recycling will be the most desirable means of solid waste management in future. Recycling has two advantages, (i) conservation of existing natural resources and (ii) sufficient reduction in the volume of refuse to be diposed. Some of the recycleable matters are paper, glass, metals and organics. Dr. Aarne Vesilind says that recovery of one ton of paper saves about 17 trees from the axe which are the sources of virgin paper. However, it is to be mentioned that the cost of manufacturing virgin paper from waste paper is more than making virgin paper directly. Though glass is a perfect recycleable product and can be used in many ways, it is a cheaper material. The availability of raw materials to prepare glass is also high. Preparation of glass from waste glasses is also expensive than original glass manufacture. The recycling of metals is profitable. Metallic wastes, metallic scraps, disposed metallic cans, wrecked automobiles can be processed and utilized in many other ways. Organics are subjected to a process known as composting. This is a method of acrobic decomposition of solid wastes in contrast to land fill. The final product obtained is termed as compost which is an excellent soil conditioner. However, it is to be noted, that in developed countries, inorganic artificial fertilizers are cheaper and the use of compost is much less. The compost is thus considered as another solid waste to be disposed.

Other ways for the control of soil pollution

The amount of solid wastes can also be controlled by other means, for example reduction at the source. But it could be done only by legislation and with the co-operation of the public.

Of all the substances that pollute the land, pesticides have given rise to the greatest public anxiety. The present trend in the manufacture of pesticides used in agriculture is to produce short-lived degradable compunds since this minimized the persistence of the residues of pesticides and their daughter products on food and forage crops.

Regarding the control of biological agents, people should adopt proper sanitary habits. The use of untreated domestic sewage also known as night soil, should be minimised. The fungi and actinomycetes should be destroyed effectively.

To conclude, soil pollution often termed as the "third pollution" is definitely a problem equal in magnitude to that of air and water pollution. About 90 per cent of the pollution of soil is caused only by solid wastes. Hence, truly biodegradable materials should be developed in future to avert soil pollution.

V

Radio-Active Pollution

Though radio-activity is a physical type of pollution it is convenient to consider radio-activity separately because the appearance of man-made radio-active materials in nature and in the economy arrived suddenly at later stages in the process of industrialisation and the nature of pollution and the effects are considerably different from other types of pollution. It is to be noted that man has been exposed to low levels of ionizing radiations from natural sources throughout his evolution. But, it is only after the advent of nuclear weapons that the exposure levels increase.

H.P. Jammet* defines radio-active pollution of the environment as the increase in natural back-ground radiation, emerging from the activities of man involving the use of naturally occurring or artificially produced radio-active materials. Radiation effects are hazardous not only to the employees engaged in radiation work but also to the general public. The chances of radioactive materials spreading into the air have increased extensively as a result of the discovery of artificial radio-activity, and particularly due to the development of atomic bomb and of techniques of harnessing nuclear energy. This chapter presents a study of factors involved in radio-active pollution of the environment, effects of the pollutants and control of radio-active pollution of the enviornment.

Environmental radiation may by divided into two types : (1) naturally occurring radiation and (2) man-made radiation.

Naturally occurring radiations are :

(i) Cosmic radiations from the outer space reaching the

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earth's surface, and
(ii) terrestrial radiation from natural radio-isotopes present in the earth's crust.

Cosmic-ray bombardment of the atmosphere continuously produces a few radio-active materials of short half-life. Among them, the important nuclides are carbon-14 and hydrogen-3 (tritium). Carbon-14 is formed by the action of cosmic-ray neutrons on atmospheric nitrogen, and hydrogen-3 is formed by the splitting of atoms when they are struck by the high-energy cosmic ray particles. Both these two are oxidised to carbon dioxide and water and they enter into the biosphere and hydrosphere.

The primary sources of natural radiations are the ores of uranium and thorium. These contain a wide variety of radio-active nuclides. They differ in chemical nature, half-life and type and energy of radiations. However, they are linked genetically into three series, each results from an element of very long half-life. The three series are, (i) uranium-radium series, (ii) thorium series and (iii) uranium-actinium series.

The other radionuclides found in nature are potassium-40 and rabidium-87. Potassium-40 constitutes about 0.012 per cent of natural potassium and rubidium-87 forms about 28 per cent of natural rubidium. Potassium-40 is said to be responsible for about 20-76 per cent of the natural radio-activity of soil. Since potassium-40 contributes radio-activity to all potassium-containing systems, it is reported that for each milligram of potassium, there will be two radio-active disintegrations per minute. Therefore, water, an environmental part will be radio-active in proportion to its potassium content including an additional contribution from biological materials. Due to its less abundance in the earth's crust rubidium-87 is considered to be relatively unimportant.

There are numerous possibilities for water to get contaminated with the above mentioned radio-active nuclides when the water runs through soils and rocks. Radon-222, the most abundable isotope of Radon, an inert gas is reported to pass through the ground and reach waters which do not possess any radio-active nuclides. Radon-222 and its immediate daughters, radium-A through radium C are the common nuclides found in radio-active springs.

Man-made radiations originate from the activities of man involving the use of radioactive materials. Radio-nuclides have numerous applications. They are used for the production of nuclear fuel and nuclear weapons, and for the production of electricity. They are extensively used as tracers in various fields. The following pages describe various processes by which radioactive contamination occurs.

Ore processing

The primary natural materials used in nuclear processes are uranium and thorium. Uranium-238 and thorium-232 are used as artificial fissionable materials. The only element in which natural fission occurs is uranium-235. Mining and refining of these materials are the first steps in nuclear technology. The waters from mining and washing processes mainly contain a small percentage of ore. The residues in the form of solids or sludges from the metallurgical units (where the ingots are produced) contain the daughter products of uranium and thorium. Of all the daughter elements, those of relatively long half-life include thorium-230, radium-226 and lead-210 (radium D) in the uranium-radium series, and radium-228 and thorium-228 in the thorium series.

The necessary isotopes of uranium and thorium are segregated from other radioactive materials by gaseous diffusion method or by some other processes. Depending upon the process used, the unnecessary radio-active materials are separated in various chemical forms. Those isotopes with long high-life will persist much longer. The more soluble materials may eventually reach and contaminate waters. Of all the radio-active nuclides, radium-226 is considered to be most harmful in a water environment due to its longer half-life biochemical properties, and the energetic radiations and its immediate daughter products. Radio-active pollution of the atmosphere also occurs through all these mining, washing, refining and separation processes as a result of the release of radio-active gases such as radon, thoron and subsequent adsorption of these products on particles present in the atmosphere and the formation of dusts from uranium or thorium ores.

Operation of reactors and nuclear fuels

The processed nuclear fuel is introduced into the reactor, the operations of which also contribute to pollution. The sequential operations are (i) Fission process, (ii) Activation process and

(iii) Thermal process. A partial transformation of the primary fuel into secondary fuel occurs in fission process with the simultaneous appearance of fission products. Fission products of the heavy metals include all the elements from about atomic number 30 (zinc) to atomic number 64 (gadolinium). The elements have excess neutrons as soon as they are formed and they rapidly change into more stable elements by radio-active decay emitting beta and gamma radiations. Activation process is one by which stable substances introduced into the channels of the reactor are activated by the neutron flux. The heat liberated during fission and activation process are converted into electricity in thermal process using coolant systems and heat exchangers. Two types of wastes are found in these processes, (i) the fission products remaining in both the primary and secondary fuels and (ii) extraneous activation products in the coolant. Thus, the fuel elements and collants constitute the sources of radioactive pollution. Fission is said to release radioactive gases such as xenon and krypton to the atmosphere.

The problem of disposal of radio-active wastes is more complicated. The radio-active wastes resulting from the above mentioned processes contain unwanted excess fission products and activation products. Since the wastes produced are in large quantities and have a high activity, they create an extremely difficult public health problem. When a fuel element is dissolved, all the fission products and heavy elements are freed from confinement and pass into the liquid. The volatile materials (inert gases and halogens), pass off as vapours. When they are released into the atmosphere, they become potential contaminant of the environment since they can settle on land or can be washed into surface waters by rain.

Nuclear weapon testing

Nuclear explosion tests threaten the world in such a manner that the natural background radiation of the environment is increased largely due to these nuclear tests. The tests including fission and fusion processes employ uranium-235 and Plutonium-239 as fission materials and hydrogen or lithium as fusion materials. Explosion, a non-moderate chain reaction, in due course results in the appearance of a very large neutron flux which makes the surrounding matters radio-active. A study revealed that the radio-active materials primarily resulted in such an explosion are fission products such as Strontium-90, Caesium-137, Iodine-131, and unused explosives and activation products. These activation products are formed by neutron bombardment of elements present in water or soil. Due to the greater force of explosion and very high temperature during explosion, the radioactive products are transformed into gases and are ejected high into the atmosphere as fine particles resulting in the atmospheric pollution. This primary pollution is followed by a secondary pollution through radio-active fall-out. These particles will subsequently be carried out or otherwise settle down on soil and water by rain and will be dispersed over the surface. Thus radio-active pollution occurs not only at the test sites but also at the remote corners.

When rain containing radionuclides falls on the ground, its activity is transferred to soil by adsorption on soil particles. As the radio-activity in the soil is available to plants, it enters the food chain resulting in the possibility of eventual ingestion by humans. When a stream receives radio-activity from fission products, through rains, the acquatic flora and fauna absorb and concentrate radio-activity. Thus once again the possibility occurs that those acquatic flora and fauna used as food by man could accumulate dangerous amounts of radio-isotopes.

The fission products are numerous out of which, strontium-89, strontium-90, Yltrium-91, Zirconium-95, Niobium-95, Ruthenium-103, Ruthinium-106, Caesium-137, Cerium-141, Cerium-144, Promethium-147, and somarium-151 are the most important long-lived fission products. The short-lived fission products comprise of molybdenum-99, iodine-131, iodine-132, tellurium-132, iodine-133, iodine-135, barium-140, praseodymium-143 and neodymium-147. All these fission products vary in nature. Some of them are insoluble in water and settle out with the particulate materials and concentrate in silts and sludges. The soluble materials remain in solution and are carried farther. Some other materials enter into the biological cycle and are distributed according to the biota present.

Radio-active materials are also released into the environment by irradiation with neutrons which are produced during an explosion. The nature and the quantity of the nuclides produced, entirely depend on the circumstances at which explosion occurs. It is reported that a high-altitude burst makes only the materials present in the bomb and air to be irradiated. It is also reported that a burst, close to the ground makes all the elements of the soil as potential sources of induced radio-activity. A subsurface explosion also converts materials such as sodium in water to be radio-active. Some of the important induced radio-nuclides are carbon-14, manganese-54, iron-55, cobalt-57, cobalt-58, iron59, cobalt-60 and zinc-65. A recent report indicates that a number of induced radio-nuclides are concentrated in biological systems and this is proved by their presence in fish.

Radio tracers

Radio tracers are extensively used in the fields of medicine industry, agriculture and biology to determine the course of chemical and biochemical reactions. Among them, C^{14} and 1^{125} are the most important tracers. Determination of "flow-through time" of sedimentation tanks and of "reaches" or "stretches" in rivers is attributed to the use of radio tracer. They are also used to determine the rate and direction of ground water.

It is reported that when waste waters containing radio tracers are discharged into sewer and rivers, some of the isotopes such as radio iodine and radiophosphorus accumulate in biological slimes and sludges. In rivers, particularly radio-active material may be concentrated by microscopic organisms which serve as food for fish and other acquatic life that are consumed by man. Thus an inherent danger occurs and it becomes a problem to consume water from the water supplies to which rivers containing radio-active wastes are contributing.

Effects of Radio-active Pollution

To know about the consequences of radio-active pollution on man and his environment, a study regarding the nature of radio-active contaminants after their discharge into the atmosphere is necessary. The effects of the pollutants largely depend on some intrinsic factors such as nature of the contaminants and also on the state of the environment. The main characteristics of all radionuclides are the decay and the subsequent emission of radiations. Each radio-nuclide has a characteristic decay constant known as half-life. Half-life may be defined as the time needed for half the atoms to decay. This period may range from a few seconds to years. Thus a radionuclide with a shorter half-life vanishes quickly and a radionuclide with a longer half-life remains years together emitting radiations. These emissions are of three types :

1. Alpha rays consisting of positively charged particles.
2. Beta rays having negatively charged particles, and
3. Gamma rays identical to X-rays, without any charge.

Alpha rays have less penetrating power; beta-rays have more penetrating power than X-rays and gamma-rays have the highest penetrating power. The energy of these radiations vary from a lower value to several million electron-volts. Thus the effects of every radioactive contaminant on living organisms depend primarily on the type of radiations and their penetrating power.

Environmental conditions also govern the fate of radio-active contaminants. Factors such as the rate of diffusion of the contaminants, the rate of sedimentation and deposition, the area of spread and the concentration of the contamination at a particular area are affected by the atmospheric conditions such as wind, temperature, climate, etc. The fate of a radio-active contaminant is also dependent on ecological conditions. An exchange between radio-active contaminants and biological environment occurs after the radio-active pollution of the environment. Biological organisms including human beings are subjected to contamination either by consumption or inhalation of radio-active contaminants. Inhalation introduces the contaminants directly into the body. An indirect path of contamination occurs through food chain. Radio-active pollution causes deposition of the contaminants on ground and surface waters. The water consumed by plants thus acts as a medium for radio-activity. Further, the radio-active contamination is passed on to vegetation and animals through the nourishment from soil and water. After nourishment the fate of the contaminant solely depends on the biological cycle that varies from organism to organism and on successive exchanges between vegetable and animal species. It is reported that secondary concentrations occur during these exchanges.

Man is considered to be the final prey for radio-active contamination and is at the end of all reactions and interactions. Direct contamination occurs through exposure to radiations by the radio-active particles in air, radio-active gases, and absorption of contaminants by respiratory tract. Indirect contamination occurs by the consumption through food chain. It is reported that zinc-65 has been accumulated in oysters at high levels, iron-55 is said to be accumulated in some fish varieties and strontium-90 is also reported to be accumulated in certain marine animals. Thus, a possibility arises that these products when consumed by man could accumulate dangerous amounts of radio-active isotopes. Moreover, some of the drinking-water sources are also reported to contain^{222}Rn, ^{226}Ra and ^{232}Th. However, treatment processes eliminate these radio nuclides.

The ill-effects due to radio-active pollution are numerous. Extensive studies have been done throughout the world and many reports have been published. Detailed information regarding metabolic changes and physiological processes are beyond the scope of this book However, some informations may be given: Radiations can cause cancers, abnormal births and mutations in man. Though these effects are common to plants and animals, such abnormalities are eliminated by the evolutionary processes of natural selection, i.e. the survival of the fittest. Since natural selection does not operate in man, radio-active pollution can produce great human misery. There is no threshold or safe-dose for radiation effects. Even the smallest increase in radiation above the natural background

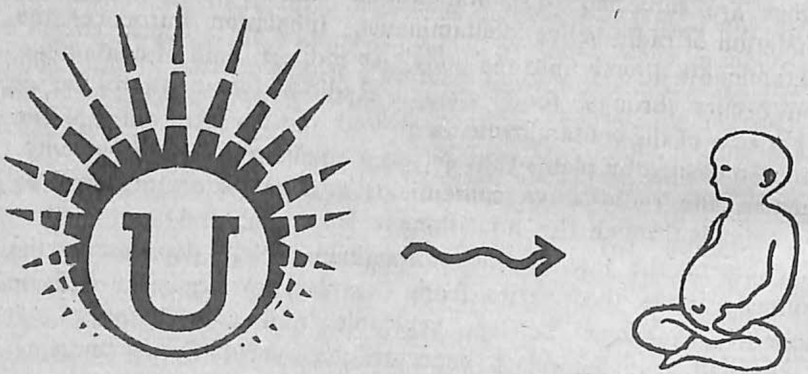

Fig 11. Radiations cause mutations and birth defects.

radiation is reported to cause risks. Chronic exposure to radiations leads to leukaemia in an individual and even affects an unborn child in the womb. Exposure to radiations causes genetic damage and affects future generations. Hence radio-active pollution is primarily a health issue of man when compared with the other environmental pollutants. Radio-active pollution thus differs from the other pollutants in the respect that it not only affects the individuals but also future generations. Moreover, the effects due to other harmful pollutants (such as DDT, PCB, etc.) are primarily on the environment while the effects of radio-active pollution are primarily on man. Modern life and habits seem to increase the risks. The radiations from medical X-rays, colour TV sets, luminous dials of clocks and watches, X-ray fluoroscopes are also contributing to the risks.

When dealing with the effects of radio-active pollution, it is good to know the maximum permissible doses also. The International Commission on Radiological Protection assessed the maximum permissible weekly dose for a radiation worker as 0.3 rem*. The maximum permissible total dose for complete life-time has been fixed as 200 rem which corresponds to 0.1 rem per week or 5 rem per year for continuous exposure. In any case the total accumumulated radiation shall never exceed 5 rem per year beyond age 18, nor shall the dose in any 13-week period exceed 3 rem. However, somewhat higher doses are also permitted where exposure is restricted to skin, bone extremities and thyroid. It has been stated that strontium-90 and radium-226 should not exceed more than 3 and 10 pCi** per litre respectively. The Federal Radiation Council has fixed a limitation to a water supply that the gross beta concentration shall never exceed 1000 pCi per litre in the known absence of alpha emitters and strontium-90.

Monitoring, prevention and control of radio-active pollution

As the radio-active pollutants are the most harmful agents it is necessary to prevent radio-active pollution. Actions have to be taken that on no account the maximum permissible doses shall over exceed. For that, rigorous monitoring system is necessary by which the nature and the level of radio-active pollutants can be determined. Preventive and control measures can then be taken according to that.

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* rem—Unit of radiation energy roentgen-equivalent-man (rem). It is the amount of radiation that will produce an energy dissipation in man that is biologically equivalent to one roentgen of radiation of X-rays or approximately equals to 1000 ergs/g. In turn roentgen (r) is a unit of X-ray or gamma-radiation intensity. It is the amount of radiation (gamma or X-ray) that produces one electrostatic unit of electricity in one cubic centimeter of dry air at N.T.P.

** pCi : 'Picocurie'—unit of radio-active disintegration also known as micro-microcurie equivalent to 3.7X10^{-2} disintegrations per second.

Monitoring techniques : Unlike other pollutants, radiation doses are measured accurately and hence a rigorous monitoring system which could be used as a model for other forms of pollution control can be set up. The monitoring techniques are discussed under the following heads :

(i) Sampling, and sample preparation for analysis.
(ii) Quantitative and qualitative analysis.

(i) *Sampling* : For the analysis, samples of air and water have to be collected. Air sampling is constituted with two processes known as gross sampling and selective sampling. Gross sampling is one by which gross samples which are representatives of the atmosphere are allowed to pass through scintillation counter or ionisation chambers. Selective sampling admits only certain components of the atmosphere. Selection of these components is achieved either by physical methods such as absorption, adsorption and filtration or by chemical methods such as precipitation. Sampling may be done either on a continuous basis or on a periodic basis.

The normal principles of sampling apply when water is sampled for the determination of its radio-activity. However, special attention has to be given to prevent the loss of radio-active material to be adsorbed on the walls of the container since the radio nuclides usually present only in the order of 10^{-12} g or less. However, glass containers and plastic containers are found satisfactory. If necessary, to minimise the adsorptive losses, acidification or addition of chelating agents or carrier materials may be employed.

Sample preparation : The techniques of sample preparation are closely linked with the type of radiation and instrumentation available. Separation of radio nuclides from water is necessary for the measurements of alpha, beta and gamma rays. Evaporation of the water and transfer of the residual materials constitute one way of separation. If a particular radio nuclide has to be determined then chemical separation may be employed. Regarding air samples granulometric methods are employed for the separation and analysis of particulate materials. Chemical methods such as ion exchange and co-precipitation are used in the separation of radio-active dusts.

(ii) *Quantitative and qualitative analysis :* Quantitative analysis is used to measure the amounts of radionuclides present and hence the level of radio-active contamination. For measuring radiations three types of method are used now-a-days. They are gas ionisation, scintillation and photographic darkening.

In addition to quantitative analysis it is necessary to do a qualitative analysis to reveal the nature of the radio-active contaminants for interpretation. The radionuclides are separated either by physical means or chemical means and they are, identified by their properties. Decay and emission characteristics of radionuclides are more important in the elucidation. The half life is a peculiar characteristic and a specific constant for a particular radio nuclide by which it can be identified. To analyse complex mixtures of radio-nuclides, based on the radiations emitted and energy of radiations, instrumentation is necessary.

Prevention and control

Since no suitable therapy has been found out for the curing of internal contamination of radio-active pollutants, it is necessary to adopt preventive measures to reduce the artificial radio-activity and steps have to be taken such that the radio-active pollution of the environment does not reach dangerous levels. It is better to know the principles underlying the preventive measures before attempting them. The rate of decay of radio-active materials and the subsequent emission of radiations are unaltered by man and hence cannot be converted into other non-toxic materials. The preventive measures should be double edged so as to curtail the effects of both occupational exposure and exposure of the population at large. All measures should so aim that the level of radio-active pollution should not exceed the maximum permissible doses.

Industrial wastes may be discharged into the environment, only after necessary treatment so that the radio-activity is at a lower level. Wastes may be discharged into sewer system or into the streams. Before discharge, it is said that the low activity wastes are stored for sometime so as to reduce the activity. In the case of high activity wastes, they cannot be discharged. The radionuclides from those wastes are segregated by coagulation, precipitation or by ion exchange. The concentrated nuclide (in solid form) is then stored or buried. Thus, after decontaminating, the waste water may be discharged. Still stronger wastes cannot be treated and they are stored indefinitely. They should never be discharged into the environment. However, the wastes may be concentrated by evaporation and the condensate with a very low activity may be discharged. The concentrated bottoms are then once again stored in special types of tanks. Now-a-days, small quantities of high activity wastes are converted into solid such as concrete and then it is buried under ground or sea. Recent reports indicate that these wastes may also be converted, into glassy or ceramic material which is then calcined to alumina or zirconia and leached. Clay may be used to take up the leached radionuclides through absorption or ion exchange after which it is fired. Firing causes the exchange in crystal structure of clay and the radionuclides cannot be leached or desorbed. Disposal of the wastes at sea has also been tried. In one type, the wastes are sealed in concrete-filled steel drums and discharged into depth of 1000 fathoms* or more. Since the disposal at sea is a costlier process underground disposal has also been suggested.

The next step in the prevention of radio-active pollution is the limitation of the emission of radio-active pollutants. This is a fruitful measure and has to be planned before the commencement of constructions. There are several techniques and according to the nature of the industry or process these techniques have to be chosen. For example, in the chemical and metallurgical industries, the use of radio-active materials may be carried out under a jet of soil (or water) instead of gaseous and powder forms. In uranium mines, wet drilling may be employed in combination with underground drainage. Closed-cycle collant systems with gaseous coolants of very high purity may be used in the case of nuclear reactors to prevent extraneous activation products. Containment may also be employed to limit the radio-active emissions. This may be achieved by using hermitically sealed boxes and closed-cycle systems. If the atmospheric radio-active pollution is still high (due to long lived isotopes), then dispersal is the only possible way. Dispersal method makes the pollutants in a confined place to spread over a large area such that the pollution is weakened and the effects are much less. Use of high chimneys and ventilation of the working place where radio-active contamination is high are some of the dispersion methods.

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* Fathom—a measure of six feet.

In the case of occupational exposure, individual contamination is more and this should be prevented. The following steps may be followed to control external radiation hazard :

1. When working with radio-active materials where it is impossible to reduce the radition, duration of exposure may be shortened by performing the operations rapidly or by using a number of workers to complete it.
2. Radio-active operations may be carried out by remaining at a sufficient distance from the source.
3. Shielding during actual work with radionuclides also minimizes the radiation dosage.

Though external radiation hazard is prevented somewhat by the above three methods, it is very difficult to curtail the internal hazard. Ingestion or inhalation of radio-active material may be prevented by proper working habits and good house keeping practices. These are regular monitoring and clean-up of surfaces, careful washing when leaving the experiment room, and no smoking, eating or drinking in the contaminated rooms. etc. Usage of mask, hood, overalls, boots, caps and gloves reduces the risk of internal contamination and risk of skin contamination. Since ingestion or inhalation of long lived isotopes causes serious consequences, the best way to protect ourselves is applying suitable preventive measures then and there.

In future, the atomic installations and processing industries may be suitably sited such that our environment will be less affected.

IV

Thermal Pollution

THE TERM "Thermal Pollution" has been used to identify the detrimental effects of heated discharges. However, the term, "thermal pollution" is not a good expression because heat itself is not a pollutant and this term does not refer to the impairment of purity by the addition of foreign matter as with water and air pollution. It denotes the impairment of the quality of environmental air or water by raising (or lowering sometimes) its temperature.

The discharge of hot trade effluents from industries, factories and mills and large volumes of warm "cooling water" from electricity generating stations may cause a temperature rise of several degrees in a river or canal. About 80 per cent of total water withdrawn for industrial operations is used for cooling only. The water drawn is discharged substantially unchanged except for an increase in temperature. The effects of these discharges are dependent on many factors. They are:

(1) Temperature difference between the discharge and the receiving water,
(2) the size of the receiving stream,
(3) the quality of receiving water,
(4) the rate of heat dissipation, and
(5) the down stream uses.

Among the industries that contribute to the thermal loading of surface waters, nuclear power plants and thermal power stations are of prime concern. Normally, the discharged water from the steam-electric power industry will have a higher temperature ranging from 6° to 10°C than the receiving water. To satisfy the tremendous need for electricity, the generating power of the installations will de raised which then need a larger proportion of stream flow. This results in the raise of steam temperature to a level at which natural dissipation of heat will be insufficient. Hence much awareness is necessary regarding this problem. Sometimes negative thermal loading also occurs during the generation of hydroelectric power. Apart from electric power industries, various industries with cooling requirements contribute to thermal loading. It is reported that about 18 per cent more heat is given to cooling waters in nuclear power plants than fossil-fuel plants of equivalent size.

Another contributor to thermal pollution is municipal sewage. Domestic sewage is usually discharged into rivers, streams or canals with or without treatment. The sewage will normally have a higher temperature than the receiving water. When sewage is discharged into water, not only the stream temperature rises to a measurable extent but also there are some other effects. The organic matter present in the sawage and other oxizdiable matter utilize the dissolved oxygen present in the surface water for oxidation. When the temperature of the receiving water is raised, the dissolved oxygen level decreases and the demand for oxygen increases and hence anaerobic conditions will set up resulting in the release of foul gases. The aquatic organisms which depend on the dissolved oxygen of the surface water will die out. Thus rise in temperature has a profound effect on water quality. The same is the case with heated industrial effluents that contain organic matter.

Effects of Thermal Pollution

The processes of life involve many chemical reactions, and the rate of these chemical reactions vary according to the changes in temperature. Apart from biochemical reactions, temperature is considered to be of vital importance to physiology and controlling reproductive cycles, digestion rates and respiration rates. The effects of thermal pollution are mainly on aquatic animals, particularly fish. Surface waters are the habitat for a wider variety of flora and fauna. The existence of these species depend only on the aquatic environment. The temperature of water is considered to be the major feature of the environment since it may affect the concentration of dissolved oxygen, pH, the rate of biochemical reactions and the physical activity of aquatic animals.

The 'thermal pollution' is a potential hazard to fish particularly.

Most species of fish can adapt themselves to a fairly wide range of water temperature, provided the temperature changes occur very slowly. Sharp changes such as sudden rise or decrease in temperature is often destructive. The temperature changes not only affect fish but also affects the entire aquatic ecosystem. Any disruption of the food chain, for example, may upset the entire system. If a change of temperature alters the seasonal variation in the types and abundances of lower organisms, then the fish may lack the right food at the right time. It is reported that both cold-water and warm-water species are found in the same latitude because of their adaptability to various temperature levels. The reason for this co-existence has been explained as follows : There is a higher level of temperature above which both type of species cannot survive. For example, brook trout lives in a temperature ranging from 4° to 24C°. But large-mouth bass survives in a temperature range of 4° to 35°C. Both these two species will survive temperatures higher than these upper limits but for a relatively short time. As with increase in temperature, fishes cannot survive below a particular temperature to which they have been

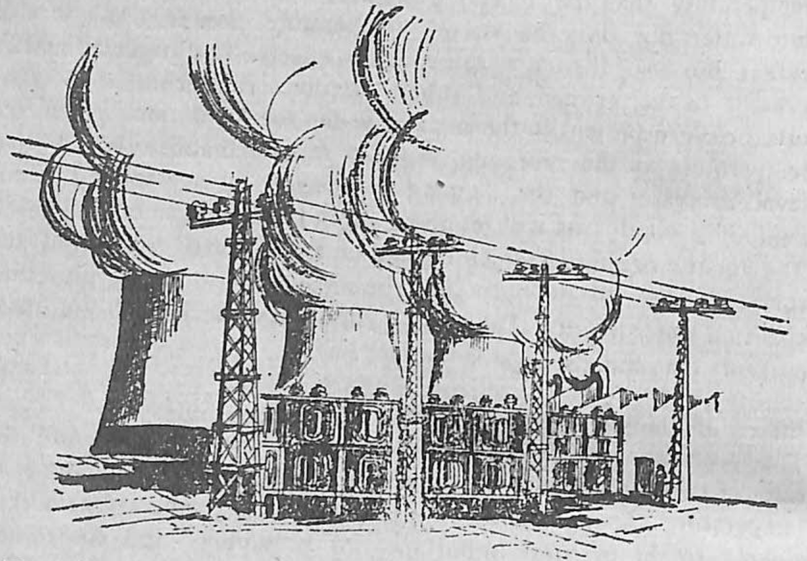

Fig 12. Thermal Pollution is mainly due to "Cooling Waters" from power generating stations.

acclimatized.

When the temperature of the aquatic system increases, the metabolic processes taking place in the body of the fish are accelerated and its need for oxygen and its rate of respiration therefore rise. Above a particular level of temperature, death occurs to fish due to failure in nervous system, or respiratory system or essential cell processes. In addition, spawning and other reproductive mechanisms are also affected during spring season.

The effect of thermal loading on dissolved oxygen concentrations is a controversial subject. It is well known that oxygen is only slightly soluble in water. As the temperature rises, the concentraion of dissolved oxygen decreases. For example, the dissolved oxygen concentration is 14.6 ppm at O° C and 7.1 ppm at 35°C. It is necessary for a healthy stream to have an adequate supply of dissolved oxygen since aquatic biota live aerobically. The drain for the nourishment of fishes depend on the concentration of dissolved oxygen. Bacteria consumes organic matter as food and the utilization of organic matter is an oxidative process. The extent of oxidation of organic matter depends on the level of dissolved oxygen. Hence in the presence of enough dissolved oxygen, bacteria multiply rapidly which in turn become the food of protozoans. These protozoans are the food for more advanced aquatic creatures. This is the food chain that provides nourishment to the fishes. All the stages of this food chain need dissolved oxygen. The dissolved oxygen in streams is replenished by two processes : reaeration and photosynthesis. Thus the consumption of oxygen by the food chain is compensated by continual replenishment.

The life in an aquatic eco-system is greatly influenced by the growth of algae. Excess nutrients from wash-out waters from farm lands combined with thermal pollution cause an excessive algae growth with consequent acceleration of eutrophic and other undesirable effects. Morever, the activities of pathogenic organisms are accelerated by higher temperatures. Thermal pollution thus makes the pathogens more virulent and the fish less resistant. As a consequence, pathogens vigorously attack fishes and a massive fish kill occurs. Such situations have long been known in the confined environments of farm and hatchery ponds, since the warming up of water is easily possible due to the lesser amount of water. As the thermal pollution load in larger water courses increases, the potential for increase of fish by disease also will be increasing.

In an unpolluted stream, diatoms grow best at 18 to 20°C; green algae, at 30 to 35°C; and blue green algae, at 35 to 40°C. Thus, thermal discharge to a water course may favour the growth of blue-green algae over green algae, resulting in a damage to the ecosystem. Blue-green algae are reported to be the poorer food source and sometimes they also become toxic to fish.

Apart from all these effects, changes in both the physical and chemical properties of water occur due to a rise in temperature. As the temperature increases, the vapour pressure increases sharply while the viscosity of water decreases. As already mentioned, the solubility of gases in water decreases with increasing temperature. These properties have important effects on aquatic life. The decrease in viscosity and density, increases the settling speed of suspended particles. The sediment load of a stream will then tend to settle more rapidly, possibly affecting aquatic food supplies. The relationship between solubility of oxygen and fish life has already been discussed. Since higher temperatures increase the rates of physiological processes and favour bacterial growth, the oxidation of oxygen demand wastes will be speeded up, due to the increased rate of oxygen depletion and thus the dissolved oxygen problem is aggravated further.

The municipal effluents consisting primarily of sewage are discharged into nearby water courses. This type of disposal method is an acceptable one where the degree of treatment conforms with the volume of the diluting water, and the forces of natural purification which includes physical, chemical and biological reaction. Purification is actually an aerobic oxidation process and complex organic matter is converted into innocuous substances by bacteria in this process. It is estimated that, the rate of biological activity doubles with each 10°C rise in temperature. This rapid activity places a corresponding burden on the dissolved oxygen resources of the water. When the water contains a higher amount of dissolved oxygen, a rise in temperature is desirable, because purification will occur more rapidly. But, when the water course contains little oxygen or if the waste to be disposed has a higher demand than the supply, then noxious conditions will develop. However, a rise in temperature generally stimulates the proliferation of photosyanthetic organisms, particularly the phytopolankton, which compensates for the deficit of dissolved oxygen. Thus warm water sometimes is beneficial though detrimental in other cases. It has also to be mentioned that colder the water (entering a purification plant), higher will be the treatment cost. Moreover warm waters are best suited for laundering purposes. But warm waters promote the growth of algae as discussed above and tastes and odours will be produced in the receiving waters.

Control of thermal pollution

Though the effects of thermal pollution are not so severe, control of thermal pollution is necessary since in future the effects may be worse. The use of water from a water course for cooling purposes, with subsequent return to the water-way after passage through the condenser is termed as once-through cooling. To reduce the magnitude of the pollution, the outlet water can be made to give up some of its heat to the atmosphere and then may be discharged into the water course. To make it effective cooling towers are primarily employed in many power stations and artificial lakes or cooling ponds are situated in some of the places.

Cooling towers

Cooling towers transfer some of the heat from cooling water to the atmosphere, most probably through the evaporation of water. Evaporative cooling towers are of two types : (1) Natural draft towers, and (2) Mechanical draft cooling towers.

Natural draft towers : In these cooling towers, hot water is sprayed down through a rising current of air. The water vapour gives its heat to the counter-current air and gets cooled. The cooled water is collected at the bottom and returned to the water body. It has to be mentioned however, that installation and operation costs are much.

Mechanical draft cooling towers : In this type of cooling towers, air flow is forced or induced by fans. Hot water, during its passage to water course gets cooled by the action of air. However, these are not preferred, since it creates annoyable noise due to the operation of fans and operation costs are also more.

Evaporative cooling towers typically cool the water by 10°C or more, but they evaporate 2 per cent or more of water during the process. One of the demerits of evaporative cooling towers is that they may form fog under some atmospheric and temperature conditions.

Just as there are evaporative cooling towers, there are also non-evaporative cooling. towers, in which heat is transferred directly to the air by means of heat exchangers. However, these are not preferable since the cost involved is much higher.

Artificial lakes or cooling ponds

These are the man-made bodies of water which offer one possible alternative to once-through cooling. The heated effluents can be discharged into the lake at one end and the water for cooling purposes may be drawn at the other end. Since the heat would eventually be dissipated through evaporation, the cooling pond would have to be replenished continuously.

Conclusion

As our future generations need more and more electricity, it is obvious that thermal pollution problems will continue to grow at a sharp rate because of dramatic increase in the electric power production. In future, the problem of thermal pollution can be alleviated by improvements in efficiencies of electric power generating plants.

VII

Noise Pollution

NOISE IS A normal feature of life and is deemed to be one of the most effective alarm systems in man's physical environment. Noise can be defined as the unwanted sound or sound without agreeable musical quality. According to Aarne Vesilind it is also the sound incidental to our civilization which we would just as soon not have to put up with. Sound is caused by the vibration of molecules and is the periodic mechanical disturbances in fluids and solids. Noise radiates from vibrating surfaces and from vibrating gases. Noise rapidly grows with increasing horse power of the machines and with increasing speed of exhaust gases. Sound travels in pressure waves and the "sound pressure" can be described in two measures : (i) the frequency of the waves that determines the pitch of the sound and (ii) the amplitude (or magnitude) which is a measure of the loudness. The frequency of sound is expressed in terms of cycles per second. The unit of amplitude is decibel (dB).

Man-made noise arises primarily from industry and transport. The sound level of some music transmitted through amplifiers is also of considerable importance. Modern civilization creates more and more noise and now noise has become a major environmental pollutant. It has increased in factories, in hospitals, at building sites and in the countryside. The power of our industrial machinery has increased enormously. It is reported that noise inside factories can become a health hazard causing deafness. Industrial noise, particularly from mechanical saws and preumatic drills is unbearable and is a nuisance to the public.

The main menace of noise, however, comes from transport. The number of road vehicles particularly diesel engine vehicles has increased enormously. Larger and faster jet aircrafts have been built over the years. The air traffic is increased to such an extent that nobody likes a new air-field in his neighbourhood. An important aspect of aeroplane noise is the sonic boom. It occurs when an aircraft like Concorde flies supersonically overhead. The sonic boom—a sudden annoyance causes significant damages to property and fright to animals. It creates mental anguish also. Thus, noise from aircraft is causing much more disquiet than that from road transport.

The noise from road transports, particularly that from heavy diesel vehicles, and motor bicycles is the most annoying form of noise. Most of the people consider it as one of the adverse factors in their environment.

A table showing the nature and distribution of noise in different human environments is given in the next page better understanding.

Effects of noise pollution

The health effects of noise are varied. The most immediate and acute one is the impairment of hearing which is caused by the damage to some part of the auditory system. Impulsive noises are generally thought to be even worse than continuous noise and capable of causing sudden damage to hearing. Acute damage occurs to the ear drum when exposed to very loud sudden noises. A more serious consequence of noise pollution is the chronic damage to the hair cells in the inner ear. Prolonged exposure to noise of certain frequency pattern will lead to temporary or permanent hearing loss. Though the impairment of hearing acuity is due to noise it cannot be attributed wholly to it since loss of hearing occurs due to increase in age even without environmental damage.

Noise has its ill-effects also on other bodily functions such as cardiovascular system. According to Mery (1968), the rate of heart beat may be affected. It may either increase or decrease depending on the type of noise. According to Kryter (1970), noise causes heart output to decrease and fluctuations in arterial blood-pressure and vasoconstriction* of peripheral blood vessels. A recent report

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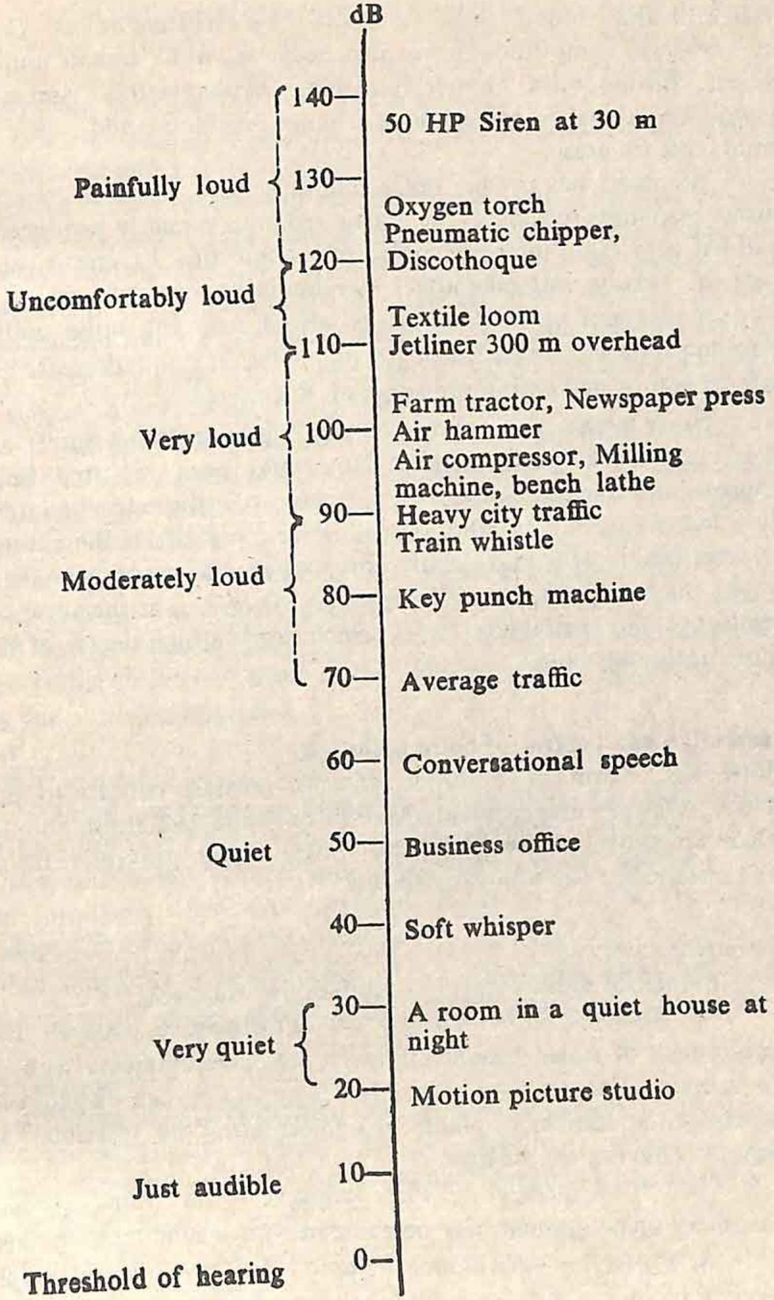
* Vasoconstriction is a physiological effect in which the small blood vessels of the body constrict and reduce the flow of blood. Vasoconstriction occurs even for short noises and persists for several minutes after-cessation of the noise.


dB
140
50 HP Siren at 30 m
Painfully loud
130
Oxygen torch
Pneumatic chipper,
120
Discothoque
Uncomfortably loud
Textile loom
110
Jetliner 300 m overhead
Farm tractor, Newspaper press
Very loud
100
Air hammer
Air compressor, Milling machine, bench lathe
90
Heavy city traffic
Train whistle
Moderately loud
80
Key punch machine
70
Average traffic
60
Conversational speech
Quiet
50
Business office
40
Soft whisper
30
A room in a quiet house at night
Very quiet
20
Motion picture studio
Just audible
10
Threshold of hearing
0

indicates that blood is also thickened by excessive noises. Changes in breathing amplitude have also been reported due to impulsive noise. Eosinophilia, hyperglycaemia, hypokalaemia and hypoglycaemia are also caused by a change in blood and other body fluids due to noise.

Mention has to be made about startle reaction—one of the direct responses to noise. The startle reaction which is produced by a sudden and high intensity pulse of sound has its effects on the nervous system and may affect psychomotor performance. It is a wonder that our optical system is also a prey for noise pollution. Pupillary dilation, impairment of night vision, and decrease in the rate of colour perception are some of the effects.

Noise which is an annoyance also causes irritation and it affects sleep and work performance. Noise has been reported both to improve and to decrease work performance depending on its intensity, duration, frequency distribution etc. Since noise affects the autonomic nervous system, it is particularly an annoyance to people who do close works such as watch repairing, etc. Moreover, as the noise causes headaches and irritability, work which needs a high degree of skill is considerably affected.

Prevention and control of noise pollution

Noise is the form of pollution causing greatest concern to public. Hence necessary arrangements have to be made and steps should be taken to control noise pollution. Some of the preventive measures are discussed in the following pages.

Industrial noise cantrol

Industrial noise control comprises the following:

1. *Reduction of noise at source:* This may be achieved by the replacement of noise producing machines of equipments with quiet alternatives. For exmple, the noise from a fan can be reduced by increasing the number of blades or by decreasing the rotational speed without reduction in air flow.

2. *Sound proofing:* For example, the noise producing machinery or equipment may be covered with insulating materials.

3. *Protection devices may be used :* For example, the employee who is a recipient of noise may wear earmuffs.

4. Acoustic zoning to prevent propagation of noise through air or solids.

Community noise control

Community noise includes noise from air traffic, road transport and construction.

The U.K. Government has introduced laws regarding the level of noise and air-lines are being subjected to international regulations. A noise advisory council has also been set up. In United States, Federal Aviation Administration has set some limits on aircraft engine noise which make the designers to produce less noise engines. With regard to sonic boom, it is purely a problem that must eventually be subject to international agreement.

Road transport produces the most annoying form of noise. The vehicle noises can be classified as (i) exhaust noise, (ii) engine intake noise, (iii) tire noise and (iv) aerodynamic noise. To reduce the pollution by vehicle noise, researches are being done to develop quieter type of diesel engines. The second possible way is routing away of highways from populated areas. The noise can be baffled with barriers such as walls etc. The fourth way is the introduction of new regulations which shall include lowering speed limits and designing for non-stop operation.

Control of other types of noises

These noises may be controlled by muffling. Our home environment also has many noises. For example, cleaning, washing operations, toilet flushing, radio, television, games, garbage disposal etc. produce noises ranging form 75 dB to 120 dB. These can be reduced by controlling the reception by the occupants. Construction noise must only be controlled by local ordinances. Town and country plannings aid in the reduction of transmission of noise.

Conclusion

From the above discussions it is now clear that noise pollution has not happened suddenly but has been in existence for several years. However, it has to be mentioned that much attention has not been given yet.

VIII

Effects of Environmental Pollution

THE KNOWN effects of pollution are numerous and varied. Probably there are many other yet to be discovered. In the next few pages some of the known effects will be discussed under the following heads :

1. Effects on humans
2. Effects on animals
3. Effects on plants
4. Effects on materials
5. Global effects.

Effects on humans

Human beings are probably the most concerned about the direct effects of pollutants upon their own health. Indeed, many of the polluting substances are beneficial, even essential, to humans but they become toxic at sufficiently high levels or doses. Some effects of pollution on humans are obviously undesirable. Among the pollutants the important ones are classified as (i) gaseous pollutants (ii) metallic contaminants, (iii) pesticides, (iv) toxic organic and inorganic compounds, (v) carcinogens, (vi) mutagens, (vii) teratogens, (viii) radio-active substances and (ix) biological contaminants. Though the effects of these pollutants are already discussed then and there, an outline of them has been given in this section also for better understanding.

Gaseous Pollution : The noxious gaseous pollutants include carbon monoxide, sulfur dioxide, and gases from the automobile exhausts. The health effects due to these pollutants may be classified as follows :

(i) Acute illness, possibly leading to death.

(ii) Chronic disease such as chronic bronchitis, pulmonary emphysema or asthma.

(iii) General untoward symptoms and irritations, including overall discomfort, nervous impairment, eye irritation and unpleasant reactions to offensive odours.

Future

Metallic contaminants

Metals : The indestructible poisons are ubiquitous in the environments. Wind and rain release metals from the rocks and soils of the earth's crust to rivers and seas. Industrial activities spread many of the metals throughout the environment. Most of the metals are poisonous to living organisms and some are essential to plant and animal life. Among them, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese and mercury are more toxic.

Arsenic : Arsenic is present in almost all types of soils in small amounts. Natural waters are also found to contain variable quantities of arsenic. Arsenic is also seen in air in micro-quantities. Artificially arsenic is introduced into the atmosphere from agricultural practices and from industries. Arsenic is a cumulative, potent, protoplasmic poison and inhibits SH-group in enzymes. Arsenic is absorbed through the lungs and skin and is the reason for diarrohoea, peripheral neuritis, conjunctivities, hyperkeratosis and lung and skin cancer. It is reported that chronic exposure to arsenic leads to the so-called "black-foot" disease in certain areas.

Barium : Barium is present in rodenticide and it is an acute poison causing hyperstimulation of cardia muscles, convulsions and kidney damage.

Beryllium : Beryllium as a pollutant is released when its alloys are produced and from the processes of nuclear power industry. It causes berylliosis (which affects the alveolar walls) and another disease known as pneumonitis.

Cadmium : It occurs in the soil, in man's food and vegetation. Chemical industries, electroplating industries, superphosphate fertilizer industries, mining and metallurgical industries contribute to the environment, cadmium as a contaminant.

It is considered that chronic cadmium poisoning causes proteinuria and it induces the formation of kidney stones. A report by Yamagata and Shigematsu (1970) indicates that a specific disease "itai-itai" (ouch-ouch) in Toyama city in Japan is due to cadmium. Further reports indicate that exposure to cadmium in air is the main cause for heart diseases, hypertension, and arteriosclerosis.

Chromium : Chromium salts are used extensively in industrial processes and also as corrosion inhibitors, and may enter a water supply through the discharge of wastes. Hexavalent chromium is toxic to aquatic and human life.

Cobalt : The main sources of cobalt are water and food (particularly beer). Excess dosage (1.5 mg/l) of cobalt results in polycythaemia and hyperlipaemia. Cobalt is also considered as a goitrogenic agent.

Copper : Copper sulfate and stabilized copper compounds are being used extensively in the treatment of reservoir water to control the growth of algae and diatoms. Copper is extremely poisonous and its effects need not be explained.

Lead : Discharge of lead occurs from the industrial process of lead smelting, manufacture of lead storage batteries, and in the mining processes. In addition to these, motor vehicles exhaust also contribute lead. Lead is a common metal used in our daily life and a definite intake of lead from water, food and air is possible. (Though it is reported that 80 micrograms of Pb per 100 gm of blood may cause poisoning, no report giving evidence regarding lead poisoning has so far been published).

Manganese : The sources of manganese are soils, fertilizers and fuel oils. Manganese in air may have adverse effects on health.

Mercury : Mercury is introduced into the environment as metallic mercury, as inorganic mercury compounds and as organic mercury compounds such as alkyl, aryl and alkoxy mercury from the process of mining and refining industries, pulp and paper industries, electronic industries, plastic industries, drug industries and chlorine-alkali plants. It is to be noted that mercury in the atmosphere is easily transformed into ethyl and dimethyl mercury. Due to its ability to combine with sulfhydryl groups it is considered that all soluble mercuric salts are toxic to all types of cells. Higher concentrations of mercury is toxic to most forms of life and it is evident that it causes chromosome damage and thus interfers with the process of heredity. Many evidences regarding the mercury poisoning have been reported (Refer WHO—Health Hazards of the Human Environment—WHO, Geneva, 1972).

Pesticides

Nowadays, danger from pesticides is increasing enormously, and newer problems are created. Though DDT, PCB and other biocides contributed much to mankind the ecological damage is equally high. The environmental deterioration due to these insecticides and pesticides is considerable. These pollutants are released into the atmosphere mainly from agricultural practices. Run-off from agricultural land contribute these pollutants to water and the discharge of industrial waste is also a main source. DDT, the non-biodegradable compound is found in all parts of the biosphere. DDT is soluble in water and will evaporate into the air and the winds carry DDT to all over the planet. This is the case with almost all biocides.

Other chlorinated hydrocarbons, Dieldrin, Aldrin, BHC, chlordane and endosulfan behave similarly and all are toxic to man. They are considered to affect the central nervous system and they also attack other vital organs.

The organic phosphorus insecticides such as parathion, malathion, and TEPP can be absorbed by the lungs, eye membranes and skin to toxic amounts and this absorption leads to the greater accumulation of large quantities of acetylcholine in the body.

Other specific inorganic and organic pollutants : In addition to the pollutants discussed above there are some other specific inorganic and organic contaminants. They are :

(i) Fluoride in drinking water
(ii) Nitrate in drinking water
(iii) Polynuclear aromatic hydrocarbons
(iv) Synthetic detergents or syndets.

Flouride : Fluoride occurs in soil, water and is released into the air in smelting processes. Fluorine is essential to human body to a particular extent. It gives a protection to the gums. Fluoride in foods and air does not seem to affect the human health in any way. But fluoride present in drinking water causes dental caries, mottled teeth, fluorosis i.e., bone and steletal disorders. When the amount of fluoride in our drinking water is 0.8 ppm it is harmless. When it exceeds this amount it is hazardous. The following table will illustrate the effects of fluoride ion when present in various concentrations in drinking water.

Amount of fluoride (in ppm)	*Effects*
1.0	Mild dental fluorosis to children.
1.7—1.8	Mottled teeth to children.
2.0	Mottled teeth and tooth disorder.
2.0—3.0	Tooth decay.
4.4—12.0	Bone disorders.
115	Dangerous to life.
2000	Very poisonous. Fatal to life.

Nitrate : Nitrate is a common ion found in water. Surface waters usually contain 5 ppm nitrate only. But the amount varies with ground waters. When the amount exceeds about 40 ppm it may cause methemoglobinaemia in infant.

Polynuclear aromatic hydrocarbons : Water and air are found to contain many polynuclear aromatic hydrocarbons, and among them, the important one is benzo(a)pyrene. These compounds are less soluble in water and are adsorbed on the surfaces. These are reported to be carcinogenic in character.

Syndets : There has been a very rapid expansion in the use of syndets. The main constituent of syndets used as the surface active agent is alkyl benzene sulfonate which is a non-biodegradable compound. This causes foaming problems in the treatment process and it is also reported to be carcinogenic. Introduction of biodegradable surface active agents seems to reduce the problem. But however the builders such as sodium tripolyphosfate are not easily removed by ordinary treatment process and there are chances for the contamination of rivers and lakes to occur by phosphates and nitrates.

Carcinogens : Carcinogens are the physical and chemical agents which produce cancer in man. A correct definition involves that a carcinogen is a substance which is known to induce or enhance neoplasia. The terms "tumorigen", "oncogen" and "blastomogen" are synonymous with "carcinogen". Carcinogens are of two types, (i) naturally occurring carcinogens and (ii) man-made carcinogens.

Naturally occurring carcinogens : The mycotoxins, particularly the aflatoxins are the widely distributed carcinogenic agents. Contamination by aflatoxins occurs in food while harvesting, storage and during transport. Some alkaloids, parascorbic acid, safrole and isosafrol have also been reported as carcinogens.

Man-made carcinogens

Aromatic amines : Industries and industrial processes introduce aromatic amines to the environment. The important compounds belonging to this category are benzidine and 2-naphthyl amine. Bladder cancer has been reported as an effect of these compounds. There are also chances for the occurrence of exposure to aromatic amines through plastics, air, foodstuffs and drinking water.

Asbestos : Though asbestos induces the diseases 'fibrosis' and 'asbestosis', it is dealt in this section since recent reports indicate that asbestos is the widely distributed carcinogen that produces lung cancer. Asbestos is a generic name given for a class of natural fibrous hydrated silicates of different chemical composition with different physical properties. Asbestos is used in a number of ways in our daily life and both the occupational and non-occupational exposure occurs. Many evidenced reports indicate that asbestos produces bronchogenic cancer also. Mesothelioma, a rare form of cancer has also been reported as a result of exposure to a particular type of asbestos.

Mutagens : Mutagens are the substances which cause mutations. Mutations are changes in the chromosomes of living cells resulting in inherited defects. Mutagens act in such a way to change the genetic material which will be transferred to daughter cells when cell division occurs and as a result the new cells possess new heritable characters. Mutagens cause birth defects i.e. abnormalities in the development of an embryo, leading it to abort or to grossly deformed new birth.

We cannot specify a particular substance as a mutagenic agent since the substance that is mutagenic in one species may not necessarily be mutagenic in other species. It depends on the other factors also. But, however, toxic chemicals, drugs, compounds considered to cause gene mutations in insects and microorganisms, compounds that are likely to be absorbed and retained by the body for long periods are considered as mutagens. Aerolein, aflatoxin benzo(a)pyrene, cumene hydroperoxide, DDT, methyl methane sulfonate, triethylene melamine are some of the proved mutagens. Radiation from radioactive materials is the best-known mutagen.

Teratogens : Teratogens are the agents considered to cause deviations during prenatal development i.e congenital malformations. The studies regarding teratogens and teratogenicity, known as teratology is a recent one and the studies relating to the mechanisms of action are much less. However, it has been reported that teratogens inhibit the normal level of growth and development of fetus during some gestational period. It has also been reported that develoment of the conceptus ceases and may result even in death. The teratogens are ranging from toxic substances to simple consumer items such as aspirin. Recent studies indicate that a substance teratogenic in man is also teratogenic to animals. Most of the teratogenic agents are primarily harmful to the embryo and not to mother. Iodine deficiency and vitamin A deficiency may induce teratogenic effect in man. Chemical agents such as thalidomide, methyl mercury, aminopterin, and carbon monoxide are considered as some of the important teratogenic agents. Ionizing radiations acting as mutagenic agents also act as teratogenic agents. Some of the micro-organisms such as cytomegalovirus, rubella virus, and herpes virus are also teratogenic. Two of the chemical defoliants 2,4-D (2,4-dichlorophenoxy acetic acid) and 2,4,5-T (2,4,5-trichlorophenoxy acetic acid) are also reported as strong teratogens.

Radio-active materials

The sources of radiation are numerous. Radio-active pollution results from the mining of radio-active ores, nuclear experiments, drainage from hospitals, industries and research institutions. A replaceable type of radio-active pollution also occurs i.e. some radio-active elements replace other elements that are present in the same family in the 'periodic table' (e.g., radium is present in the same family of calcium and the former replaces the latter). When such elements are present in food or drink, they tend to replace other substances 'isolectronic' with them. Since aquatic flora and fauna can absorb and concentrate radio-activity, the possibility exists that those used as food by man could accumulate dangerous amounts of radio-active isotopes. Apart from all, primarily the danger arises through the increased production of nuclear weapons.

Radiations consisting of X-rays, α,β-and γ-rays, produce both the somatic and genetic effects. The varied effects of radiation depend on so many factors such as, physical and chemical nature, their radio-active half-lives, the level of energy of the radioactivity, their metabolism within the body and their excretion rates. The more important health effects caused by the radio-active materials are the following: blood abnormalities, including anaemia, leukaemia and haemorrhagic diseases, thyroid changes, bone changes—bone necrosis and bone sarcoma, skin changes, including erythema, atrophy, pigment changes, alopecia and ulceration and lung changes—fibrosis and cancer.

Radiations cause damage to germ cells. The damage is of two types: (i) "lethal mutations" also known as "genetic deaths" and (ii) "non-lethal mutations".

Biological contaminants :

In addition to the above pollutants, our environment also contains biological contaminants. Their effects on human health are still worse. There are numerous biological contaminants and a detailed study of them is beyond the scope of this book. However, an outline regarding air-borne microorganisms (mainly from air pollution), pathogenic bacteria, viruses and parasites (the latter three from water pollution) may be given as follows:

(i) *Air-borne microorganisms*: The air-bone microorganisms have been reported to cause cerebrospinal meningitis (particularly at dry seasons), anthrax, histoplasmosis and coccidioi domycosis. Infection by the spores of coccidioides imitis is said to be the reason for coccidioidomycosis. It is also reported that 'air-borne infections' always occur at enclosed spaces such as schools and hospitals.

(ii) *Pathogenic bacteria:* These are the principal sources of morbidity and mortality in many developing countries. The infection by pathogenic bacteria causes epidemic diseases such as cholera, typhoid, diarrhoea, dysentery and other enteric diseases. Among the pathogens, vibriocholera, salmonella and shigella group species are important ones.

(iii) *Viruses:* These viruses are found in sewage and polluted waters. The most common viruses found in sewage and polluted water are adenoviruses, enteroviruses, and neoviruses and the virus that causes infectious hepatitis.

(iv) *Parasites:* The parasites normally causing ill-health are (1) Entamoeba histolytica, (2) Guinea-worm, (3) Ascaris lumbricoides, (4) Trichuris trichiura and (5) Fasciola.

Entamoeba histolytica causes intestinal amoebiesis (e.g., amoebic dysentery) and other extra-intestinal forms of the disease such as amoebic liver abscess. It can be seen in almost all temperate countries with poor sanitation. The guinea-worm causes dracontiasis. Cysts of Fasciola in water ·has been reported to be the reason for 'distomatosis', a parasitic disease.

Apart from all, noise is also considered as a pollutant. Whether in connection with work environment, with highway, urban or air traffic or in the home, the sources of noise are numerous, and their effects on health and well-being are manifold.

Repeated exposure in the course of employment to high noise levels may lead to deafness. To a lesser extent the impairment of hearing aouity with age may be accelerated by exposure to noise. Noise has in addition a number of non-specific physiological effects such as changes in the cardio-vascular and respiratory systems in the eyes, in galvanic skin responses and in the blood and other body fluids. The psychophysiological effects are also reported which are felt mainly in connection with sleep, the disturbance of which may affect the health adversely in the long-run. The annoyance caused by noise has an increasing psychosocial effect, both individually and collectively on work performance.

Effects on Animals

Environmental pollution causes serious health problems to animals also. Air pollutants are known to produce eye and respiratory irritation in animals. The most serious effect is the poisoning of livestock by fluorides and by arsenic. The effects of fluoride arise from the fall out of various fluorine compounds on forage. The ingestion of these pollutants by cattle causes an abnormal calcification of bones and teeth called fluorosis, resulting in loss of weight and lameness. Arsenic poisoning is less common and has been transmitted by contaminated gases near smelters. Sewage, toxic chemicals and disease producing organisms can make water unfit for use by farm animals and when such a contaminated water is consumed by the animals, many ill-effects will appear.

Water pollutants can also endanger aquatic life and every year, millions of fish are reported to be killed by municipal sewages and industrial wastes. Thermal pollution, by which the water in rivers, streams and lakes get excess heat can kill fish and other aquatic life. It is reported that pesticide levels in many species of birds have reduced the reproduction rates through mechanisms such as interference in calcium metabolism.

Effects on Plants

Air pollution plays an important role in affecting plant life. There has been widespread damage to trees, fruits vegetables and ornamental flowers by air pollution. For example, fluorides which act as cumulative poisons to plants cause collapse of leaf tissues. Photochemical smog is proved to bleach many plants such as spinach, lettuce, tobacco, alfalfa and other leafy plants. Ethylene released from automobile exhausts, makes carnation petals curl inward and it ruins orchids by drying and discolouring their sepals. It is to be noted that retardation of growth of plants may occur, even when pollution levels are not high enough to produce noticeable injury. Some plants are more sensitive than others to the pollutants (the pollutant may be air or water pollutant or radiation) and hence there may be complex changes in the plant ecosystem. Sometimes, the pollutants cause undesirable effects such as increase in plant life through the introduction of plant nutrients. For example, in many of the water bodies in which nutrients such as nitrogen, phosphorus and carbon are concentrated, algal blooms can be seen.

Effects on Materials

Pollution can accelerate the deterioration of materials and construction. Acidic air pollutants, particularly sulfur dioxide gas and sulfuric acid aerosols can corrode metals and building materials. They also cause weakening or disintegration of textiles, paper and marble. Hydrogen sulfide, an odoriferous air pollutant blackens leaded house paints. Ozone, as already indicated produces cracks in rubber. Particulate pollutants causes erosion of building surfaces. Water pollutants, such as suspended particles and dissolved inorganic compounds, can adversely affect pumps, industrial equipments, bridges, and other materials of this type. The noise produced by sonic booms can even damage the buildings and break windows.

Global Effects

Over the past century, pollutants have been discharged into environment in mounting quantities. Apart from other effects, these pollutants also affect the climate of the earth as a whole. Human activities might affect the world climate is several ways which are discussed briefly in the following pages.

Effect on climate by increase in carbon dioxide levels

Carbon dioxide enters the atmosphere naturally as a water product from respiration of human beings, animals and plants and through the decomposition of living tissues. In addition, many of the industrial processes and domestic activities contribute much to carbon dioxide. A report by World Meterological Organization indicates that a doubling of the present carbon dioxide content of the atmosphere would raise the temperature of the earth's surface by about 1.3°C (Refer Chapter II, "Air Pollution"). The United States Council on Environmental Quality has suggested that if all the fossil fuels of the earth were burned, and half of the resulting carbon dioxide retained in the atmosphere* (See foot note), the temperature of earth's surface might increase by 2 to 3°C. With a result the ice in polar regions would begin to thaw and the sea level will consequently be increased. But however, this is not possible, since there has been a general cooling of the earth over the last ten years (at least in the northern hemisphere) (see next paragaraph). The suggested reason is that the dust particles released into the atmosphere act as screens to the incoming solar radiations and thus cause a cooling effect. Both these two factors (rise in temperature and decrease in temperature) seem to be true. Hence more research is needed to judge the controversy.

Effects of dust particles

Dust particles are considered to form more nuclei about which water vapour could condense or freeze to form rain droplets or ice particles. Consequently, the skies become more cloudy and the atmospheric turbidity increases. The more the turbidity, less will be the penetration of solar radiations to the earth. It has been reported that a 10 per cent increase in atmospheric turbidity can cause a cooling of the climate by about 1°C. However, dust particles also absorb heat from sun and earth which have something of a compensating effect.

Effects of exotic chemicals

The exhaust gases from rockets contain certain substances which are not present in the upper atmosphere normally. These substances may pollute the upper atmosphere and produce changes which might affect the layer of ozone which protects the earth's surface from harmful ultra-violet radiations. The screen by ozone against the ultra-violet radiation depends upon the concentrations of ozone as low as a few parts per million. The formation and maintenance of ozone screen depends largely on complex chemical processes which might be upset by the pollutants.

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* About half of the released carbon dioxide dissolves in oceans, and the remaining half is retained in the atmosphere. The carbon content of ocean is about 60 times than that of atmosphere. Most of the carbon in ocean, is present in the form of sodium, and magnesium carbonates. An exchange of carbon between atmosphere and oceans is also reported.

Effects on climate due to changes in land use

The heat and water vapour of the atmosphere are mostly received through the boundary layer at the earth's surface. The conditions at this boundary can be altered by the way man uses the land. The extent of radiation that is reflected from the ground surface depends on the nature and extent of the vegetation cover. A forested area presents a dark surface to the incoming radiations and much of heat is absorbed, while a bare ground receives lesser radiations and the rate of reflection is also much high. Further, the heat absorbed by the vegetation is used by them but that of a bare ground is merely reflected and the surrounding water and air gets heated. Thus the clearance of forests and their replacement by grassland or cultivation causes changes in the local pattern of heating of ground and atmosphere.

Conclusion

Although many factors regarding the global effects have been known, the long-term effects are still not known. Our knowledge of the physical and chemical processes that take place within the atmosphere and at the interface between air and ocean is still inadequate. It is to be emphasized that wtihout adequate knowledge of natural long-term oscillations, the impact of pollutants on the climate of the earth cannot be assessed. Hence it is important to maintain researches in this field.

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Printed at Sarswati Art Printers, New Anaj Mandi, Delhi-110 006.

At a time when environmental pollution is increasing day by day, this brief but comprehensive book will prove to be of great help and guidance for layman as well as for students involved in public health engineeing. Starting with a consideretion of the general nature of pollution, the author discusses the major areas of pollution like air, water and soil, touching on thermal radiation and noise pollution and their deleterious impact on man and environment alike. This book also highlights the various methods of prevention and control of various kinds of pollution in an easy, non-technical way.

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